U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 94.

L. O. HOWARD, Entomologist and Chief of Bureau.

INSECTS INJURIOUS TO FORESTS AND FOREST PRODUCTS.

I. DAMAGE TO CHESTNUT TELEPHONE AND TELEGRAPH POLES BY WOOD-BORING INSECTS.

By THOMAS E. SNYDER, M. F., *Agent and Expert.*

II. BIOLOGY OF THE TERMITES OF THE EASTERN UNITED STATES, WITH PREVENTIVE AND REMEDIAL MEASURES.

By THOMAS E. SNYDER, M. F., *Entomological Assistant Forest Insect Investigations.*

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1916.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Entomologist and Assistant Chief of Bureau.*
E. B. O'Leary, *Chief Clerk and Executive Assistant.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
——————, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
A. F. Burgess, *in charge of gipsy moth and brown-tail moth investigations.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *in charge of library.*

Forest Insect Investigations.

A. D. Hopkins, *Forest Entomologist in charge.*

H. E. Burke (in charge of Pacific Slope Station at Placerville, Cal.), Josef Brunner (in charge of Northern Rocky Mountain Station at Missoula, Mont.), T. E. Snyder, W. D. Edmonston (in charge of Southern Rocky Mountain Station at Colorado Springs, Colo.), F. C. Craighead, J. M. Miller (in charge of seed insect station at Ashland, Oreg.), and A. B. Champlain, *assistants in forest entomology.*
L. C. Griffith, *assistant in shade tree insects.*
S. A. Rohwer, *specialist on forest Hymenoptera* (in charge of Eastern Station at East Falls Church, Va.).
A. G. Böving, *specialist.*
C. T. Greene, *specialist on forest Diptera.*
W. S. Fisher, *specialist on forest Coleoptera.*
Carl Heinrich, *specialist on forest Lepidoptera.*
Jacob Kotinsky, *entomological assistant.*
William Middleton, *scientific assistant.*

PREFACE.

Bulletin 94, entitled "Insects Injurious to Forests and Forest Products," consists of two parts and an index.

Part I, "Damage to Chestnut Telephone and Telegraph Poles by Wood-Boring Insects," by Thomas E. Snyder, comprises the results of a special study of a serious damage to the base of standing chestnut telephone and telegraph poles by the wood-boring larva of a beetle designated by the author as the chestnut telephone-pole borer (*Parandra brunnea* Fab.).

Part II, "Biology of the Termites of the Eastern United States, with Preventive and Remedial Measures," by Thomas E. Snyder, is based mainly on investigations and experiments conducted during the past three years by Mr. Snyder in connection with his work in the Branch of Forest Insect Investigations. It also includes unpublished notes by Messrs. H. G. Hubbard and F. L. Odenbach. Termites are among the most destructive insects to both crude and finished forest products in North America, among which may be listed construction timbers in bridges and wharves, telephone and telegraph poles, hop poles, mine props, fence posts, lumber piled on the ground, railroad ties, and the woodwork of buildings. The sudden crumbling of bridges and wharves, the caving in of mines, and the settling of floors in buildings, are sometimes directly due to the concealed work of these insects. The use of untreated wood-pulp products, such as the various composition-board substitutes for lath, etc., is restricted in the Tropics and southern United States because of the ravages of termites. In the cities of Washington, Baltimore, St. Louis, Cleveland, New York, and Boston, and throughout the eastern and southern United States, damage by termites to the woodwork of buildings is occasionally serious.

Methods of prevention and control against injuries to finished and utilized forest products, etc., are based on the results of experiments conducted by this branch of the bureau.

A. D. Hopkins,
Forest Entomologist.

CONTENTS.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

ERRATUM.

Page 10, footnote *a*, for *Priorus* read *Prionus*.

INSECTS INJURIOUS TO FORESTS AND FOREST PRODUCTS.

DAMAGE TO CHESTNUT TELEPHONE AND TELEGRAPH POLES BY WOOD-BORING INSECTS.

By Thomas E. Snyder, M. F.,
Agent and Expert.

OBJECT OF PAPER.

It has recently been determined through special investigations conducted principally by the writer that serious damage is being done to the bases of standing chestnut telephone and telegraph poles in certain localities by the grub or larva of a wood-boring beetle, here called the chestnut telephone-pole borer.[a] The character and extent of the damage under different conditions of site in several localities have been determined, and poles treated with various preservative substances have been inspected to compare the efficiency of both chemicals and methods of treatment. These investigations have resulted in the determination of practical methods of preventing injury to poles by wood-boring insects.

HISTORICAL DATA.

The first information of serious damage to standing chestnut poles by wood-boring insects was conveyed in a letter, dated December 15, 1906, from E. O. Leighley, a correspondent of this Bureau, reporting damage to telephone poles in Baltimore, Md., by borers. Mr. A. B. Gahan, assistant entomologist of the Maryland Agricultural Experiment Station, College Park, Md., who investigated the injury to the poles, stated that it was the work of a borer and was located just beneath the surface of the ground. Mr. Gahan brought specimens of the work and the insect to this office. The borers were identified as cerambycid larvæ, and later were determined to be the chestnut telephone-pole borer (*Parandra brunnea* Fab.).

On December 16, 1906, Mr. H. E. Hopkins, division superintendent of a telephone company, stated that the poles in West Virginia were

[a] *Parandra brunnea* Fab.; Order Coleoptera, Family Spondylidæ.

badly injured by borers and that these borers were abundant. On March 8, 1907, he collected larvæ from chestnut telephone poles at Pennsboro, W. Va. These were determined to be the larvæ of the chestnut telephone-pole borer.

The writer on October 3, 1909, inspected some chestnut telegraph poles which had been standing for about twelve years on New York avenue, in Washington, D. C. The poles had been taken down under orders from the city authorities, which necessitated the placing of wires in conduits under ground, and they had been lying in piles for about a month before they were inspected. The chestnut telephone-pole borer had been working in the base of the poles, and white ants, or termites, were associated with them. Twelve out of the 103 poles examined had been damaged, some more seriously than others.

On October 15, 1909, Mr. H. E. Hopkins sent a reply to a request by Dr. A. D. Hopkins for further information regarding insect damage to poles in West Virginia. He stated that in one line built twelve years ago (40 miles long, 36 chestnut poles to the mile, poles 20 to 40 feet long and 5 to 12 inches in diameter at the top) approximately 600 poles had been rotted off at the top of the ground, and inspection showed that 95 per cent of the damage was directly or indirectly due to insects. Other lines in this division were reported to be in about the same condition. It was later determined that most of the insect damage was the work of the chestnut telephone-pole borer.

Dr. A. D. Hopkins states in a recent comprehensive bulletin [a] that "construction timbers in bridges and like structures, railroad ties, telephone and telegraph poles, mine props, fence posts, etc., are sometimes seriously injured by wood-boring larvæ, termites, black ants, carpenter bees, and powder-post beetles, and sometimes reduced in efficiency from 10 to 100 per cent." Thus, while it has been known that almost all classes of forest products that are set in the ground are seriously injured by wood-boring insects, the problem of insect damage to standing poles, posts, and other timbers has never been made the subject of a special investigation.

In May, 1910, this study was assigned to the writer, and, in addition to a study of the insects involved, investigations in cooperation with telephone and telegraph companies have been conducted in the District of Columbia, Maryland, Virginia, Pennsylvania, New Jersey, and New York. Through the courtesy of the Western Union Telegraph Company several telegraph lines were inspected in July and August, 1910, in Virginia, where the poles were being reset or replaced. Here the butts of over 200 poles set under different conditions of site were thoroughly examined for insect damage, and sometimes the

---

[a] Insect Depredations in North American Forests. <Bul. 58, Part V, Bureau of Entomology, U. S. Department of Agriculture, p. 67, 1909.

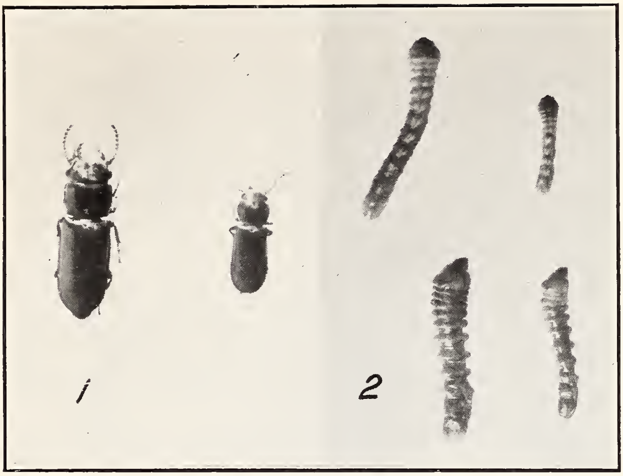


FIG. 1.—THE CHESTNUT TELEPHONE-POLE BORER (PARANDRA BRUNNEA): MALE AND FEMALE BEETLES. FIG. 2.—THE CHESTNUT TELEPHONE-POLE BORER: YOUNG LARVÆ, DORSAL AND LATERAL VIEWS. FIG. 1, SLIGHTLY ENLARGED; FIG. 2, TWICE NATURAL SIZE. (ORIGINAL.)

FIG. 3.—DAMAGE TO AN UNTREATED CHESTNUT TELEGRAPH POLE NEAR SURFACE OF GROUND BY THE CHESTNUT TELEPHONE-POLE BORER. (ORIGINAL.)

entire pole was split open. In one line 10 to 12 years old (approximately 30 chestnut poles per mile, 25 feet long, about 6 inches diameter at the top, 10 inches at the base, and apparently of second quality), between Petersburg and Crewe, Va.—the poles had already been reset once, east of Wilson, Va.—serious damage by the chestnut telephone-pole borer rendered from 15 to 20 per cent of the poles unserviceable. After the present second resetting it was estimated that the poles can not last more than four or five years longer. West of Wilson the poles were naturally in much worse condition, and many were broken off and only held up by the wires on the sounder poles. In another line examined, between Portsmouth and Boykins, Va. (poles 30 feet long and apparently of second quality), serious damage by this borer averaged about 10 or 15 per cent, and between Boykins, Va., and Weldon, N. C., according to a linesman, 50 per cent of the poles are badly decayed near the surface of the ground. Much of this damage, however, is due to fungous heart rot. According to a statement by the foreman of a resetting crew, between Asheville, N. C., and Spartanburg, S. C., hundreds of chestnut poles were badly decayed in the 67 miles of line reset, and were only held up by the wires. The line was 15 years old. There was serious damage by "wood lice" (termites) and also by "white wood worms."

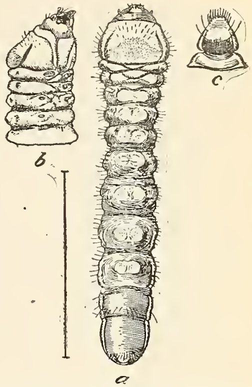


FIG. 1.—The chestnut telephone-pole borer (*Parandra brunnea*): Full-grown larva. (About twice natural size. (Original.)

THE CHESTNUT TELEPHONE-POLE BORER.

(*Parandra brunnea* Fab.)

CHARACTER OF THE INSECT.

The chestnut telephone-pole borer is a creamy white, elongate, stout, cylindrical, so-called "round-headed" grub or "wood worm" (fig. 1), which hatches from an egg deposited by an elongate, flattened, shiny, mahogany brown, winged beetle from two-fifths to four-fifths of an inch in length. (Plate I, fig. 1; text fig. 2.) The eggs are probably deposited from August to October in shallow natural depressions or crevices on the exterior of the pole near the surface of the ground; often the young larvæ enter the heartwood through knots. The young borers (Plate I, fig. 2) hatching therefrom eat out broad shallow galleries running longitudinally in the sapwood, then enter the heartwood, the mines being gradually enlarged as the larvæ develop. As they proceed, the larvæ closely pack the fine excreted boring dust behind them. This débris, which is characteristic of

their work, is reddish to dunnish yellow in color and has a claylike consistency. The mines eventually end in a broad chamber, the entrance to which is plugged up by the excelsior-like fibers of wood chiseled out by the strong mandibles of the larva. Here the resting stage (fig. 3), or pupa, is formed, and in this chamber the perfect adult spends considerable time before emerging. Often all stages from very young larvæ only about one-fourth inch long to full-grown larvæ over 1 inch long, pupæ, and adults in all stages to maturity are present in the same pole. Adults have been found flying from July to September. As yet the seasonal history of this borer has not been completely worked out.

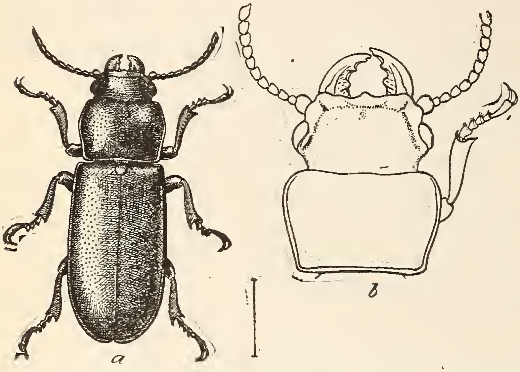


FIG. 2.—The chestnut telephone-pole borer: Female beetle, three and one-half times natural size. Head and pronotum of male beetle. (Original).

DISTRIBUTION.

This insect is very widely distributed, ranging from Ontario, Canada, to Texas, eastward to the Atlantic coast, and westward to Arizona and southern California. It is common throughout the natural range of the chestnut—and in this connection it should be observed that most of the chestnut poles are purchased from local timber-land owners.

CHARACTER OF THE INJURY.

The injury to the poles consists in large mines in the wood near the line of contact of the pole with the ground, necessitating the frequent resetting or even the replacement of the damaged poles. These irregular galleries of the grub (Plate II, fig. 1) run both horizontally and longitudinally throughout the heartwood, and are sometimes 7 inches long, but vary with the individuals, which show great differences in size. The borers usually work in the outer layers of the wood at the base of the pole for a distance of from 2 to 3 feet below, and sometimes from 1 to 2 feet above the line of contact of the pole with the surface of the ground. The greatest damage is to that area just below and just above the surface of the ground (Plate I, fig. 3); here the conditions of air and moisture are most favorable. Often the entire butt up to a distance of from 4 to 6 feet and higher, according to the depth of setting, is mined. The numerous galleries, often very close together, completely honeycomb the wood in a zone

FIG. 1.

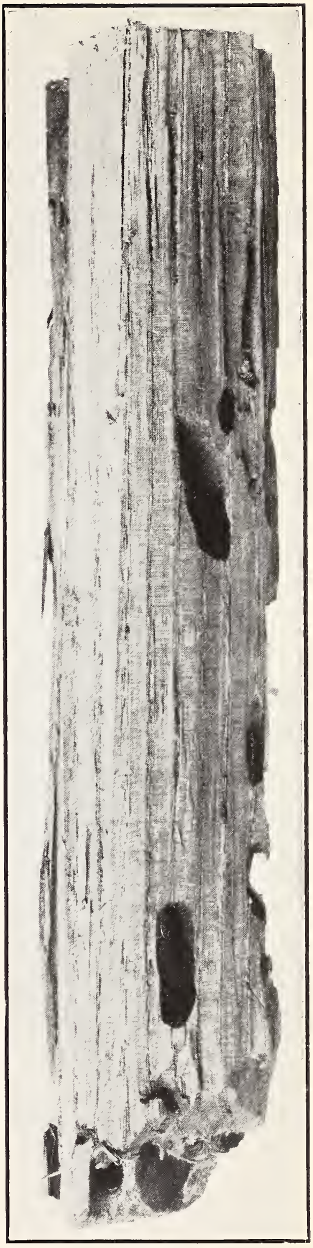


FIG. 2.

WORK OF THE CHESTNUT TELEPHONE-POLE BORER.

Fig. 1.—Gallery of the chestnut telephone-pole borer, showing pupal chamber with the entrance plugged with excelsior-like wood fibers; work near base of pole, below ground. Fig. 2.—Mines of the chestnut telephone-pole borer near surface of ground. Natural size. (Original.)

3 to 4 inches in from the exterior of the poles; this so weakens the poles that they break off close to the surface of the ground. The basal 2 feet is usually sound. Even if the damage is not serious enough to cause the poles to break off under strain, they are likely to go down during any storm, and thus put the wire service out of commission; such damaged poles are a serious menace along the right of way of railroads. The beetle will attack poles that are perfectly sound, but evidently prefers to work where the wood shows signs of incipient decay; it will not work in wood that is "sobby" (wet rot), or in very "doty" (punky) wood. It has not yet been determined just how soon the borers usually enter the poles after they have been set in the ground. However, poles that had been standing only four or five years contained larvæ and adults of this borer in the heartwood, and poles that had been set in the ground for only two years contained young larvæ in the outer layers of the wood.

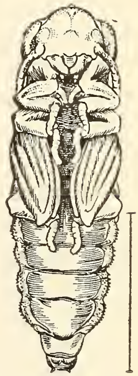


Fig. 3.—The chestnut telephone-pole borer: Pupa. Slightly more than twice natural size. (Original.)

Poles that appear sound on the exterior may have the entire basal interior riddled, and the work of the borers is not noticed until the poles break off. If merely isolated poles are injured, the poles that are broken off are held up by the wires and can be detected by the fact that they lean over, but if several adjacent poles are affected, especially where there is any unusual strain, that portion of the line is very likely to go down. The presence of the borers in injurious numbers can be determined only by removing the earth from about the base of the pole; the exit holes of the borer are found near the line of contact with the soil. Often large, coarse borings of wood fiber project from the exit holes. Sometimes old dead parent adults are found on the exterior of the poles underground. During August the young adults may be found in shallow depressions on the exterior of poles below the ground surface.

IMPORTANCE OF THE PROBLEM.

The subject of the relation of insects to the rapid decay of chestnut poles has not been thoroughly investigated in the past, but now that the supply is becoming scarcer it is especially important to know what are the various primary causes of the deterioration of these poles, hitherto described under the vague term "decay." Although the chestnut telephone-pole borer has not hitherto been considered an insect of any economic importance, and has been described in entomological literature as only living under bark, principally of pine, or

in the decomposing wood of various species of deciduous and coniferous trees, the evidence is abundant that breeding in the bases of chestnut poles is not a newly acquired habit. It has also been determined that this beetle damages many species of living forest, fruit, and shade trees that have been previously injured by fire or other causes, and often leads to the destruction of trees that would otherwise recover from such wounds, and while not normally a primary enemy to trees, may thus become of more than secondary importance.

The damage by the chestnut telephone-pole borer is especially serious in consideration of the fact that in many parts of its range the chestnut is threatened with extinction as a tree species on account of the very severe ravages of the combined attack of an insect [a] and a fungous disease. Further unnecessary drain upon the supply of chestnut timber should be avoided by protecting that already in use and thus prolonging its length of service.

EXTENT OF DAMAGE AND LOSS.

As more than one-fourth of the 3,500,000 round poles exceeding 20 feet in length used annually by telephone, telegraph, and other electric companies are chestnut (Kellogg, 1909),[b] and as this borer has seriously damaged as high as 10 to 40 per cent, varying with conditions of site, of the chestnut poles which have been set in the ground for from ten to twelve years in lines in North Carolina, Virginia, West Virginia, Maryland, and the District of Columbia, it is evident that this insect is an important factor in decreasing the normal length of service of the poles.[c] In lines from twelve to fifteen years old the damage is much greater, and at the end of this number of years of service any line in which poles of this species are set has to be practically renewed. According to a statement in Forest Service Bulletin 78 (Sherfesee, 1909), "approximately 4 per cent, or 5,908 feet board measure of the 147,720 feet board measure of standing poles annually requiring replacement in the United States, is destroyed by insects." If only chestnut poles be considered, at least 10 per cent of the poles reset or replaced are injured by insects.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR DESTRUCTIVE WORK.

The damage is apparently greatest and the borers are most abundant where the poles are set in high or level dry ground under good conditions of drainage. Such sites are the crests of railroad cuts through low hills, slopes of "fills," and in cultivated or other fields. Where the poles are in wet sites there is usually but little injury by

---

[a] *Agrilus bilineatus* Web.

[b] See list of publications, page 11.

[c] The average life of a chestnut pole is eight to ten years (Sherfesee and Weiss, 1909).

wood-boring insects except to that portion near the surface of the ground. Conditions of drainage are more important than different soil combinations, and the condition of the soil is more important than its composition; *i. e.*, where the soil is hard packed there is apparently less damage than where it is loose. The quality and condition of the poles before setting is a very important factor to consider before arriving at any conclusions as to the relative longevity of poles under various conditions of site. Green (unseasoned) or imperfectly seasoned poles are less durable than those thoroughly seasoned. Poles that are defective [a] before setting, as they very often are (i. e., showing evidence of incipient decay), and poles that have the heartwood mined by the chestnut timber worm,[b] the work of which is very abundant, will, of course, decay much more rapidly than poles that are in an absolutely sound condition. The galleries of the chestnut timber worm afford an entrance to the spores of wood-destroying fungi, and thus greatly accelerate decay. White mycelium compactly filled these galleries throughout many standing poles, thus clearly proving that these mines aid greatly in enabling the fungous heart rot more rapidly and completely to penetrate the entire heartwood of the poles. If the injury by both wood-boring beetles and wood-destroying fungi (between which there is a varying interrelation) be considered, then in several lines from ten to twelve years old in North Carolina, Virginia, and West Virginia at least 50 per cent of the poles are either rendered unserviceable or their length of service is much shortened.

ASSOCIATED WOOD-BORING INSECTS.

It is not to be concluded that this wood-boring beetle is the only insect that injures standing chestnut poles. Indeed, the most common injury is by the "wood lice" or white ants.[c] In lines from ten to twelve years old these insects have seriously damaged as high as 15 per cent of the poles, and their work is often present, at least superficially, in as high as 75 per cent of the poles under all conditions of site. However, the damage is usually to the outer layers of the wood, where it is moist or there is incipient decay, and is more superficial and localized than that of the chestnut telephone-pole borer. Nevertheless, white ants often completely honeycomb the sound heartwood of poles, especially at the base. They work both in sound wood, "doty" (dry rot) wood, and "sobby" (wet rot) wood. Sometimes a large channel runs up through the core of the heart

---

[a] Often this evidence is the old galleries of the destructive two-lined chestnut borer (*Agrilus bilineatus* Web.), showing that the tree must have been dead before it was cut for a pole, and hence is more likely to be defective throughout the interior; in other instances heart rot is clearly present.

[b] *Lymexylon sericeum* Harr.

[c] Identified by Mr. Theodore Pergande of this Bureau as *Termes flavipes* Kollar.

and the sides are plastered with clay, forming a hollow tube with several longitudinal galleries. Their work often extends from 2 to 4 feet above the surface of the ground. They leave the outer shell of the wood intact and work up through the longitudinal weathering checks, covering the exterior of the pole with earth to exclude the light. White ants will damage poles that have been set in the ground only two years. Evidently they enter the pole from below the surface of the ground. The habits and characteristics of these peculiar and interesting insects have been thoroughly discussed in Circular No. 50 of this Bureau by Mr. C. L. Marlatt.

A giant round-headed borer [a] is sometimes found in the poles, usually in association with the chestnut telephone-pole borer. In poles where the wood is sound this borer apparently works as a rule only in the outer layers of the wood, the galleries running longitudinally through the heart below the surface of the ground. In poles where there is decay it will completely honeycomb the heartwood near the surface of the ground.

In several poles where the wood was "doty" a large Scarabæid [b] which has before been found in decayed oak railroad ties was present and caused the poles to break off sooner than they otherwise would. The irregular galleries of the grub completely honeycomb the decayed heartwood near or just below the surface.

A flat-headed borer [c] and wireworms [d] were found in galleries locally in the more or less decayed heartwood of several poles. A large black carpenter ant [e] does some damage to sound poles set in dry ground through woodland. This ant often widens the longitudinal weathering checks and thus accelerates decay. A small black ant [f] was very numerous in many poles, but its work is usually confined to the outer layers of the wood. The work is often throughout "doty" poles. Injury by this ant is not primary, but it also widens weathering checks, enlarges other defects, and induces more rapid decay.

PREVENTION OF THE INJURY.

Doctor Hopkins makes the following statement in a recent bulletin:[g]

> Insect damage to poles, posts, and similar products can be prevented to a greater or less extent by the preservative treatments which have been tested and recommended by the Forest Service for the prevention of decay. These should be applied

[a] *Prionus* sp.

[b] Identified by Mr. E. A. Schwarz, of this Bureau, as *Polymœchus brevipes* Lec.

[c] Identified by Mr. H. E. Burke, of this Bureau, as *Buprestis rufipes* Oliv.

[d] Species of the family Elateridæ. The large larvæ of *Alaus* sp. were especially injurious.

[e] Identified by Mr. Theodore Pergande as *Camponotus pennsylvanicus* Mayr.

[f] Identified by Mr. Theodore Pergande as *Cremastogaster lineolata* Say.

[g] Insect Depredations in North American Forests. <Bul. 58, Part V, Bur. Ent., U. S. Dept. Agr., p. 84, 1909.

before the material is utilized for the purposes intended, or, if it be attacked after it has been utilized, further damage can be checked to a certain extent by the use of the same substances.

It is often of prime importance to prevent injury from wood-boring insects, for the reason that such injuries contribute to more rapid decay. Therefore anything that will prevent insect injury, either before or after the utilization of such products, will contribute to the prevention of premature deterioration and decay.

Through the courtesy of the American Telephone and Telegraph Company and the Forest Service, about 40 chestnut poles set in a test line near Dover, N. J., were inspected by the writer on July 15, 1910, in company with engineers of the telephone company and Mr. H. F. Weiss, Assistant Director, Forest Products Laboratory, Forest Service, to determine the relative merits of various methods of preventing damage by wood-boring insects to the bases of poles. In this line, which is eight years old, variously treated poles alternated with untreated poles in order that each chemical preservative and method of treatment might be given an absolutely fair test under the same conditions of site. The poles were 30 feet long, 7 inches in diameter at the top, and 33 inches in circumference 6 feet from the base. In this inspection the earth was removed (to a depth of about 1 foot) from the base of the pole, and then the pole was chopped into to determine the rate of decay. This method of inspection for insect damage is not very satisfactory. The various methods experimented with in this test line were brush treatments with a patented carbolineum preservative and spirittine, charring the butt, setting the pole in sand, and setting it in small broken stone. It was found that, although these methods may temporarily check the inroads of wood-boring insects, they will not keep the insects out of the poles. The most serious damage to the poles in this line was by white ants. Other insect damage was by a large black carpenter ant[a] and the larvæ of a round-headed borer.[b]

An inspection was made, between September 6 and 14, 1910, of the bases of over 400 chestnut poles set in a similar test line near Warren, Pa., and Falconer, N. Y. These poles were treated by the creosote "open-tank" method of impregnation, and brush treatments of creosote, wood creosote, creolin, two different carbolineum preservatives, and tar; they had been set in the ground for a period of five years. All these treatments, except the brush treatments with creolin and tar, were efficient in preventing the attacks of wood-boring insects, at least for a five-year period, in this northern climate. There was but little damage by insects to the poles in this test line. The most common injury to the untreated poles was by the large black carpenter ants which widen the longitudinal weathering checks, and hence induce more rapid decay. The work of the chestnut tele-

---

[a] *Camponotus pennsylvanicus* Mayr.
[b] *Prionus* sp.

phone-pole borer was found in several poles, and this beetle was evidently just beginning to attack these poles. There was some damage by a round-headed borer.[a] No white ants or termites were present, and this is evidently too far north for these destructive borers. A report by inspectors of the American Telephone and Telegraph Company and the Forest Service on the remainder of the poles in this test line (between Jamestown and Buffalo, N. Y.) not personally inspected by the writer, showed that these conclusions can be applied to all the poles in the line with the exception that there was superficial injury by small black ants to two poles treated by brush treatments of carbolineum avenarius and to two treated with wood creosote; also, as the inspection progressed, injury by the chestnut telephone-pole borer became more abundant and serious, and the borers seemed to be established in the poles. The poles treated by the creosote "open-tank" method of impregnation and by brush treatments with creosote and with "S. P. F." carbolineum remained uninjured.

Methods of treating poles superficially by brushing with various preservatives have proved to be temporarily efficient in keeping wood-boring insects out, if the work is thoroughly done and not only the butt, but also the base, is treated. If the pole is not thoroughly brushed, insects enter through the untreated or imperfectly treated portions, especially through weathering checks and knots. Where the base is left untreated, insects, especially white ants or termites, enter the pole from below ground and, avoiding the treated portions, come right up through the pole.

The few poles of southern yellow pine in a line near Bartley, N. J., inspected on July 15, 1910, which had been impregnated with creosote by the Bethell cylinder-pressure process, 12 pounds of oil to the cubic foot, and had been set in the ground since February, 1903, were apparently absolutely free from signs of decay or damage by wood-boring insects. In another line, running between Norfolk, Va., and Washington, D. C., the few poles (12 years old, of squared—with the sapwood cut away—southern yellow pine) inspected on August 10, 1910, near Portsmouth, Va., which had been impregnated with creosote by the Bethell cylinder-pressure process, were also apparently absolutely sound.

Thus, it is evident that impregnating the poles with creosote by some standard process (either the open-tank or the cylinder-pressure processes) will keep wood-boring insects out and preserve the poles for a much longer period than they would last untreated. In the open-tank method only the area most subject to the attacks of wood-boring insects and deterioration in general (i. e., the basal 8 feet) is treated, while by the cylinder-pressure processes the entire pole is impregnated. Alternating less susceptible juniper (red cedar)[b] poles

[a] *Priorus* sp.

[b] *Juniperus virginiana*.

or pine poles thoroughly impregnated by some standard process in the line with the chestnut poles would be a safeguard in holding up an old line where the damage is found to be serious on resetting.

A list of some available publications on wood preservation is appended.

PUBLICATIONS ON WOOD PRESERVATION AND STATISTICS ON POLES.

1903. Von Schrenk, H.—Seasoning of timber. <Bul. 41, Forest Service, U. S. Dept. Agr.

1906. Grinnell, H.—Prolonging the life of telephone poles. <Yearbook U. S. Dept. Agr. for 1905, Extract No. 395.

1907. Crawford, C. G.—The open-tank method for the treatment of timber. <Cir. 101, Forest Service, U. S. Dept. Agr.

1907. Crawford, C. G.—Brush and tank pole treatments. <Cir. 104, Forest Service, U. S. Dept. Agr.

1907. Grinnell, H.—Seasoning of telephone and telegraph poles. <Cir. 103, Forest Service, U. S. Dept. Agr.

1908. Sherfesee, W. F.—A primer of wood preservation. <Cir. 139, Forest Service, U. S. Dept. Agr.

1908. Weiss, H. F.—Progress in chestnut pole preservation. <Cir. 147, Forest Service, U. S. Dept. Agr.

1909. Sherfesee, W. F.—Wood preservation in the United States. <Bul. 78, Forest Service, U. S. Dept. Agr., pp. 24, 25, Table I.

1909. Sherfesee and Weiss.—Wood preservation. <Rep. Natl. Conserv. Com., vol. 2, p. 663.

1909. Kellogg, R. S.—The timber supply of the United States. <Cir. 166, Forest Service, U. S. Dept. Agr., pp. 20–21.

1910. Willis, C. P.—The preservative treatment of farm timbers. <Farmers' Bul. 387, U. S. Dept. Agr.

INSECTS INJURIOUS TO FORESTS AND FOREST PRODUCTS.

BIOLOGY OF THE TERMITES OF THE EASTERN UNITED STATES, WITH PREVENTIVE AND REMEDIAL MEASURES.

By Thomas E. Snyder, M. F.,
Entomological Assistant.

INTRODUCTION.

The following notes on the biology of the common termites,[a] or "white ants," of the eastern United States were, for the most part, made while conducting investigations to determine the character and extent of damage by termites and other forest insects to various classes of crude and finished forest products and to devise methods of preventing the injury. During 1910 and 1911 special investigations were conducted by the writer as to the character and extent of damage to telephone and telegraph poles and mine props by wood-boring insects. This contribution is thus based, largely, on these investigations, as well as on additional experiments conducted during the past three years by the writer in the branch of Forest Insect Investigations and on some of the unpublished notes of the late H. G. Hubbard and those of Rev. F. L. Odenbach.

"White ants" are among the most destructive insects of North America to both crude and finished forest products, among which may be listed construction timbers in bridges, wells, and silos, timbers of wharves, telephone and telegraph poles, bean and hop poles, mine props, wooden cable conduits, fence posts, lumber piled on the ground, railroad ties, and the foundations and woodwork of buildings, etc. The sudden crumbling of bridges and wharves, caving in of mines, and settling of floors in buildings are sometimes directly due to the hidden borings of termites. The use of untreated wood-pulp products such as the various "composition boards" used as substitutes for lath, etc., is restricted in the Tropics and portions of the southern United States because of the ravages of termites. In the cities of Washington, Baltimore, St. Louis, Cleveland, and New York, and throughout the Southern States damage by termites to

[a] Order *Platyptera*, Packard (1886), suborder *Isoptera*, Brullé (1832), family *Mesotermitidæ*, Holmgren, genus *Leucotermes* Silvestri.

the woodwork of buildings is occasionally serious. As far north as Boston, Mass., damage of this sort occurs, and in Michigan cases are reported in which furniture in buildings has sunk through the floors, mined by "white ants."

The preventives and remedies against injury to forest products and nursery stock herein given are based on the results of experiments conducted by the Bureau of Entomology. The species to be considered in this paper are *Leucotermes flavipes* Kollar and *Leucotermes virginicus* Banks. The former is widely distributed [a] over the United States, but the recorded distribution of the latter is more limited.[b]

CLASSIFICATION.

Termites are naturally to be classed among that most interesting group of social insects comprising the ants, bees, wasps, etc., since they live in colonies which are made up of various highly specialized forms or castes. Each of these forms has a distinct rôle in the processes of the social organization, as there is a well-defined division of labor. In the systematic classification of insects, however, termites are widely separated from the other social insects. These latter represent the highest and most specialized development, whereas termites represent the lowest and are among the oldest of insects. Furthermore, in many points in their life habits termites are widely different from the other social insects.

The tropical genus Termes, from which the family and generic names of termites are derived, is a Linnæan creation [c] and appears for the first time in 1758, in the tenth edition of Systema Naturæ, where it was placed among the Aptera, between the genera Podura and Pediculus. Since then termites have been classed [d] among the orders Neuroptera, Corrodentia, and Pseudoneuroptera, although Brullé, in 1832 (Expéd. Sc. Morée, t. 3 (Zool.), p. 66, Paris, 1832), had founded the distinct new order Isoptera.[e] Packard,[f] in 1863, stated that "seven out of the eight well-established families of the Neuroptera sustain a synthetic relation with each of the six other suborders." Hagen,[g] in 1868, stated in regard to the error that he made in describ-

[a] Marlatt, C. L. The White Ant (*Termes flavipes* Koll.). U. S. Dept. Agr., Bur. Ent., Circ. 50, pp. 8, figs. 4, June 30, 1902. See p. 4.

[b] Banks, N. A new species of Termes. Ent. News., v. 18, no. 9, p. 392–393, November, 1907.

[c] Desneux, J. Isoptera, Fam. Termitidæ, pp. 52, figs. 10, pls. 2. (Wytsman, P., Genera Insectorum, fasc. 25, Bruxelles, 1904, p. 1–3.)

[d] Feytaud, J. Contribution à l'étude du termite lucifuge. Arch. Anat. Micros., t. 13, fasc. 4, p. 481–606, figs. 34, 30 juin, 1912.

[e] Desneux, J. Loc. cit.

[f] Packard, A. S. On synthetic types in insects. Boston Jour. Nat. Hist., v. 7, no. 4, p. 590–603, fig. 4, June, 1863.

[g] Hagen, H. A. Proc. Boston Soc. Nat. Hist., v. 12, p. 139, October 21, 1868, Boston, 1869.

ing [a] a damaged earwig (Forficula) from Japan as a wingless termite, "that the three families, Termitina, Blattina, and Forficulina, are coordinated and very nearly allied." Packard,[b] in 1883, placed termites in a new order, the Platyptera, including the Termitidæ, Embiidæ, Psocidæ, and Perlidæ, and three years later he dismembered [c] the Pseudoneuroptera into the Platyptera, Odonata, and Plecoptera. Knower,[d] in 1896, stated that in the development of the embryo of termites there is a resemblance to that of the Orthoptera. Desneux, in 1904,[e] stated that termites are derived phylogenetically from the "Blattides," an idea accredited to Handlirsch in 1903, although Hagen, in 1855, had already formulated this theory based on purely biological considerations. Comstock,[f] in 1895, also placed termites in the order Isoptera. Enderlein,[g] in 1903, placed termites with the Embiidæ in the order Corrodentia, suborder Isoptera. In this order he also placed the Psocidæ and Mallophaga. Handlirsch [h] contests the affinity of the Termitidæ with the Embiidæ; he further states [i] that termites are derived from all deposits from the lower Tertiary on, but that all older fossils formerly mistaken for termites by Hagen, Scudder, and Heer do not belong to this order. Banks [j] (1909) considered termites to be in the order Platyptera, suborder Isoptera, with two other suborders, the Mallophaga and Corrodentia. Holmgren states[k] that he believes both groups, the "Termiten" and "Blattiden," are offshoots of a more primitive group, the "Protoblattoiden." The oldest "Blattoiden" occur in the first part of the middle, upper Carboniferous (Pottsville, North America), the oldest "Protoblattoiden," in the last

---

[a] Hagen, H. A. On a wingless white ant from Japan. Proc. Boston Soc. Nat. Hist., v. 11, p. 399–400, illus., February 26, 1868.

[b] Packard, A. S. Order 3, Pseudoneuroptera, U. S. Dept. Agr., U. S. Ent. Com., 3d Rept., p. 290–293, 1883.

[c] Packard, A. S. A new arrangement of the orders of insects. Amer. Nat., v. 20, no. 9, p. 808, September, 1886.

[d] Knower, H. McE. The development of a termite—*Eutermes* (*Rippertii?*) A preliminary abstract. Johns Hopkins Univ. Circ., v. 15, no. 126, p. 86–87, June, 1896.

[e] Desneux, J. Loc. cit.

[f] Comstock, J. H. Manual for the Study of Insects. Ithaca, N. Y., 1895, p. 95–97, fig. 104–106.

[g] Enderlein, G. Über die Morphologie, Gruppierung und Systematische Stellung der Corrodentien. Zool. Anzeig., vol. 26, p. 423–437, figs. 4.

[h] Handlirsch, A. Zur Systematik der Hexapoden. Zool. Anzeig., vol. 27 (1904), p. 733–769.

[i] Handlirsch, A. Die fossilen Insekten und die Phylogenie der rezenten Formen, pt. 8, p. 1240, Leipzig, 1908.

[j] Banks, N. Directions for Collecting and Preserving Insects, pp. 135, figs. 188, Washington, 1909. U. S. Nat. Mus. Bul. 67. Platyptera, p. 6–7.

[k] Holmgren, N. Termitenstudien 1. Anatomische Untersuchungen. K. Svenska Vetensk. Akad. Handl., Bd. 44, No. 3, pp. 215, Taf. 1–3, Uppsala & Stockholm, 1909. Die Verwandtschaftsbeziehungen der Termiten, p. 208–213.

part of the coal measures (Allegheny, North America), but the youngest "Protoblattoiden" occur in the lower Permian formation of Europe. Holmgren considers the termites to be in a distinct order, the Isoptera.

The order Isoptera, according to Holmgren (1911),[a] is divided into three families, the Protermitidæ, the Mesotermitidæ, and the Metatermitidæ. All of these families are represented in North America, and while this paper is restricted to a discussion of species of the genus Leucotermes Silvestri, subfamily Leucotermitinæ Holmgren, family Mesotermitidæ Holmgren, a species in the genus Termopsis Heer, subfamily Termopsinæ Holmgren, family Protermitidæ Holmgren, is briefly mentioned. Thus it will be seen that the species under observation occupy a middle position between the highest and the lowest genera in the systematic classification of termites.

HISTORICAL.

According to Desneux, Smeathman's marvelous descriptions in Some Account of the Termites Which Are Found in Africa and Other Hot Climates (London, 1781) are the real basis of scientific researches on the biology of termites.[b] Hagen [c] gives a résumé of the researches on termites up to 1860. Drummond's Tropical Africa (London, 1889), in chapter 6, gives an interesting account of "white ants." Froggatt, in Australian Termitidæ,[d] gives a résumé of the studies of various workers on termites. Saville-Kent, in Chapter III of the Naturalist in Australia (London, 1897), describes the habits of termites in the Tropics; Smeathman, Drummond, and Saville-Kent in their popular accounts of termites stimulated interest in the habits of these insects and led to scientific researches. Grassi and Sandias,[e] in their classical work, have outlined the results of the more important biological researches. Sharp[f] gives an excellent

[a] Holmgren, N. Termitenstudien 2. Systematik der Termiten. K. Svenska Vetensk. Akad. Handl., Bd. 46, No.6, pp. 86, Taf. 1–6, Uppsala & Stockholm, 1911. Ordnung Isoptera, p. 10–11.

[b] Smeathman, H. Some account of the termites, which are found in Africa and other hot climates. In Philos. Trans. London, v. 71, p. 139–192, 3 pls., 1781. (Smeathman's observations were afterwards confirmed by Savage in 1850 and the late G. D. Haviland.)

[c] Hagen, H. A. Monographie der termiten. Linnæa Entomologica, v. 10, 1855, p. 1–144, 270–325; v. 12, 1858, p. 1–342, pl. 3; v. 14, 1860, p. 73–128.

[d] Froggatt, W. W. Australian Termitidæ, Part I. Proc. Linn. Soc. N. S. Wales, v. 10, ser. 2, p. 415–438, July 31, 1895. Distribution, p. 416–426.

[e] Grassi, B., and Sandias, A. The constitution and development of the society of termites; observations on their habits; with appendices on the parasitic protozoa of Termitidæ and on the Embiidæ translated by F. H. Blandford. Quart. Jour. Micros. Sci. [London], v. 39, pt. 3, n. s., p. 245–322, fold. pl. 16–20, November, 1896, and v. 40, pt. 1, p. 1–75, April, 1897.

[f] Sharp, D. Cambridge Nat. Hist., vol. 5, Insects, Pt. 1, chap. 16, p. 356–390, London, 1901.

summary of the various writings on termites up to 1901. Escherich[a] gives a résumé of the more important work up to 1909, and also an extensive bibliography. Holmgren's treatise[b] deals with anatomy, systematic classification, development, and biology, and gives a summary of the effect of the social life, as shown in the progressive and retrogressive development of termites. Bugnion[c, d] has recently made observations that lead him to state that (in *Eutermes lacustris* Bugnion and *Termes* spp.) the differentiation of the three castes occurs in the embryo. Feytaud[e] has published an account of the life history of *Leucotermes lucifugus* Rossi, a species closely related to our common species of the eastern United States. His observations confirm those of Heath on the same species in this country. He also made studies of the internal anatomy. The more important contributions to our knowledge of termites are the results of researches by Bobe-Moreau, Bugnion, Czervinski, Desneux, Doflein, Drummond, Escherich, Feytaud, Froggatt, Grassi and Sandias, Hagen, Haldemann, Haviland, Holmgren, Jehring, Latreille, Leidy, Lespès, Fritz Müller, Pérez, Perris, Petch, Rosen, Savage, Silvestri, Sjöstedt, Smeathman, Wasmann, and many others. In the United States, Banks, Buckley, Hagen, Heath, Howard, Hubbard, Joutel, Knower, Marlatt, Porter, Schaeffer, Schwarz, Scudder, Stokes, Strickland, and Wheeler have contributed to the knowledge of the habits of our native species. The following paragraph gives a brief résumé of the more important researches on the biology of the common species of Leucotermes in the United States.

H. A. Hagen contributed several articles on the habits of *flavipes*, and has described forms[f, g] found by the late Mr. H. G. Hubbard, of the Division of Entomology. Hubbard, many of whose unpublished notes are herein included, was the first to find royal individuals, both

---

[a] Escherich, K. Die Termiten . . . eine biologische Studie, p. 2–7, Leipzig, 1909.

[b] Holmgren, N. Termitenstudien 3. Systematik der Termiten. Die Familie Metatermitidæ. K. Svenska Vetensk. Akad, Handl., Bd. 48, No. 4, 166 p., Taf. 1–4, Uppsala & Stockholm, 1912.

Blick auf dem mutmasslichen, stammesgeschichtlichen Entwicklungsverlauf der Termiten, p. 129–153.

Holmgren, N. Termitenstudien 2. Systematik der Termiten. K. Svenska Vetensk. Akad. Handl., Bd. 46, No. 6, pp. 86, Taf. 1–6, Uppsala & Stockholm, 1911. Ordnung Isoptera, p. 10–11.

[c] Bugnion, E. La differenciation des castes chez les termites [Nevr.]. Bul. Soc. Ent. France, 1913, no. 8, p. 213–218, April 23, 1913.

[d] Bugnion, E. Les termites de Ceylan. Le Globe: Memoires, Soc. Geog. Geneva, t. 52, p. 24–58, 1913.

[e] Loc. cit.

[f] Hagen, H. A. The probable danger from white ants. Amer. Nat., v. 10, No. 7, p. 401–410, July, 1876.

[g] Riley, C. V. Social insects from psychical and evolutional points of view. Proc. Biol. Soc. Wash., v. 9, p. 1–74, figs. 12, April, 1894.

true and neoteinic, in the United States, and his material forms an important auxiliary to later investigations. Much of Hubbard's collecting in Florida and Arizona was done in company with Mr. E. A. Schwarz, of the Bureau of Entomology, who has since published[a] some of his observations on the habits of termites in southwestern Texas. The Rev. F. L. Odenbach, S. J., of Cleveland, Ohio, has studied the habits of our native species of termites since 1893, and has contributed many manuscript notes. Mr. L. H. Joutel, of New York, has studied the habits of our common species[b] and has contributed some unpublished notes. Dr. H. McE. Knower,[c] late of Johns Hopkins University, in 1894 published new and important contributions on the embryology of termites (Eutermes). His observations are not in accord with those of Bugnion, since he determined that the nasutus develops from a worker-like larva nearly as large as a young nasutus, having 13 joints to the antenna and worker-like head and jaws. This worker-like larva had a small head gland with no "corne frontale" on the outside of the head, although sections show essentially the same structure in the gland as that of the nasutus. Mr. C. Schaeffer, of Brooklyn, N. Y., was the first to record[d] the presence of a fertilized true queen of *flavipes* in a colony. The researches[e] of Dr. Harold Heath, of Stanford University, Cal., on the habits of California termites confirm the statements of Pérez and Perris that some colonizing individuals of *Leucotermes lucifugus* succeed in establishing new colonies. Mr. Nathan Banks, of the Bureau of Entomology, has contributed several articles on our native termites, and has described a new species of Leucotermes (*virginicus*)[f] from the eastern United States. Mr. C. L. Marlatt, assistant chief of the Bureau of Entomology, has described the distribution, life history, and destructiveness of *flavipes* in the United States and figured the castes.[g] Mr. E. H. Strickland,[h] Carnegie scholar in economic entomology at Bos-

---

[a] Schwarz, E. A. Termitidæ observed in southwestern Texas in 1895. Proc. Ent. Soc. Wash., v. 4, No. 1, p. 38–42, Nov. 5, 1896.

[b] Joutel, L. H. Some notes on the ravages of the white ant (*Termes flavipes*). Jour. N. Y. Ent. Soc., v. 1, No. 2, p. 89–90, June, 1893.

[c] Knower, H. McE. Origin of the "Nasutus" (soldier) of Eutermes. Johns Hopkins Univ. Circ., v. 13, No. 111, p. 58–59, April, 1894.

[d] Schaeffer, C. Jour. N. Y. Ent. Soc., v. 10, No. 4, p. 251, December, 1902.

[e] Heath, Harold. The habits of California termites. Biol. Bul., v. 4, No. 2, p. 47–63, January, 1903.

[f] Banks, N. A new species of termes. Ent. News, v. 18, No. 9, p. 392–393, November, 1907.

[g] Marlatt, C. L. The White Ant (*Termes flavipes*, Koll.). U. S. Dept. Agr., Bur. Ent., Circ., No. 50, rev. ed., pp. 8, figs. 4, June 27, 1908.

[h] Strickland, E. H. A quiescent stage in the development of *Termes flavipes* Kollar. Jour. N. Y. Ent. Soc., v. 19, No. 4, p. 256–259, December, 1911.

ton, Mass., has described and illustrated a quiescent stage in the development of the nymph of the first form of *Leucotermes flavipes*, which stage was discovered by Prof. W. M. Wheeler, of Bussey Institute.

While investigating damage to the bases of telegraph poles by wood-boring insects a large fertilized true queen of *Leucotermes flavipes* was found by the writer on August 12, 1910.[a] The finding of this interesting form, usually considered to be rare in colonies of our native termites, served as an incentive to further biological study on the habits of our common species. On August 11, 1911, molting

FIG. 4.—View at Falls Church, Va., showing a portion of the treated experimental stakes under test, as to the relative effectiveness of preventives against termite attack. (Original.)

larvæ in the quiescent stage were observed by the writer for the first time, in a colony in Illinois. Special investigations were begun at Falls Church, Va., in March, 1912, to determine (1) the habits of our common termites, (2) the effectiveness of various methods and chemical wood preservatives in preventing attack by our native termites (fig. 4), and (3) the "immunity" (?)[b] or relative resistance of native and tropical species of wood.[c]

---

[a] Snyder, T. E. Record of the finding of a true queen of *Termes flavipes* Kol. Proc. Ent. Soc. Wash., v. 14, No. 2, p. 107–108, June 19, 1912.

[b] It is doubtful if any species of native wood of economic importance is absolutely immune to termite attack.

[c] Impregnation of wood to resist insect attack. Amer. Lumberman, Nov. 15, 1913

BIOLOGICAL EXPERIMENTS.

THE TERMITARIUM.

Early in March, 1912, work was begun on a large outdoor termitarium, at Falls Church, Va. The projects outlined for study in connection with the termitarium were (1) to observe the progressive development of the termite from the larva to the adult, especially in the case of the colonizing form; (2) to watch the insects when they swarmed, to determine whether this swarming is a nuptial flight, i. e., whether or not the sexes leave the nests in separate swarms and at what time copulation occurs; (3) to observe how the new colony is established, (4) in what proportion the pairs survive, and (5) the conditions in the parent colony after the swarm is over.

The termitarium was merely a large cage in which the termites could swarm under conditions as nearly similar to those in nature as possible. The cage consisted of a bottom of galvanized iron in the form of a rectilinear box sunk in the ground to the depth of a foot, a framework of wood to support the wire netting, and a wooden roof covered with tarred paper. The bottom of the cage consisted of a galvanized-iron box 10 by 6 feet and 1 foot deep, of 27-gauge galvanized sheet iron with an inch flange turned inwards. (Fig. 5, *a.*) This box was raised off the ground on a wooden floor of seven-eighths inch material, 4 inches wide, which was laid on 2 by 4 inch studding. There was an air space of 1 inch between the sides of the box and the earth, as well as a similar space between the sheet-iron bottom and the earth. The top of the sheet-iron box was nailed to a framework of 2 by 4 inch studding, which was supported on cedar posts, the top of the box being several inches above the surface of the ground. Loose earth was placed in the box to about half its depth, over which was spread a shallow layer of black earth (leaf mold) from the forest floor, for the purpose of retaining moisture. The wooden framework consisted of 2 by 4 inch studding, which was covered on the inside with galvanized-wire netting (14 squares mesh per inch) and reinforced at the side and ends by boards 4 inches wide by seven-eighths inch thick. The cage is about 7 feet in height, and the roof, slanting away from a shed against which it is built, acquires sufficient pitch to shed rainfall. (Fig. 5, *b.*)

Two chestnut logs which had been cut and allowed to season about one month before the experiment was begun were placed in the cage. One was placed on end in the dirt, the top of the log approximating the height of a stump, while the other, a tangential section, was partially buried in the ground. The bark was loosened, but was left intact on both logs. The logs were both sound, but were kept moist. A number of small decaying branches and strips of decaying chestnut boards were also laid flat upon the earth in the

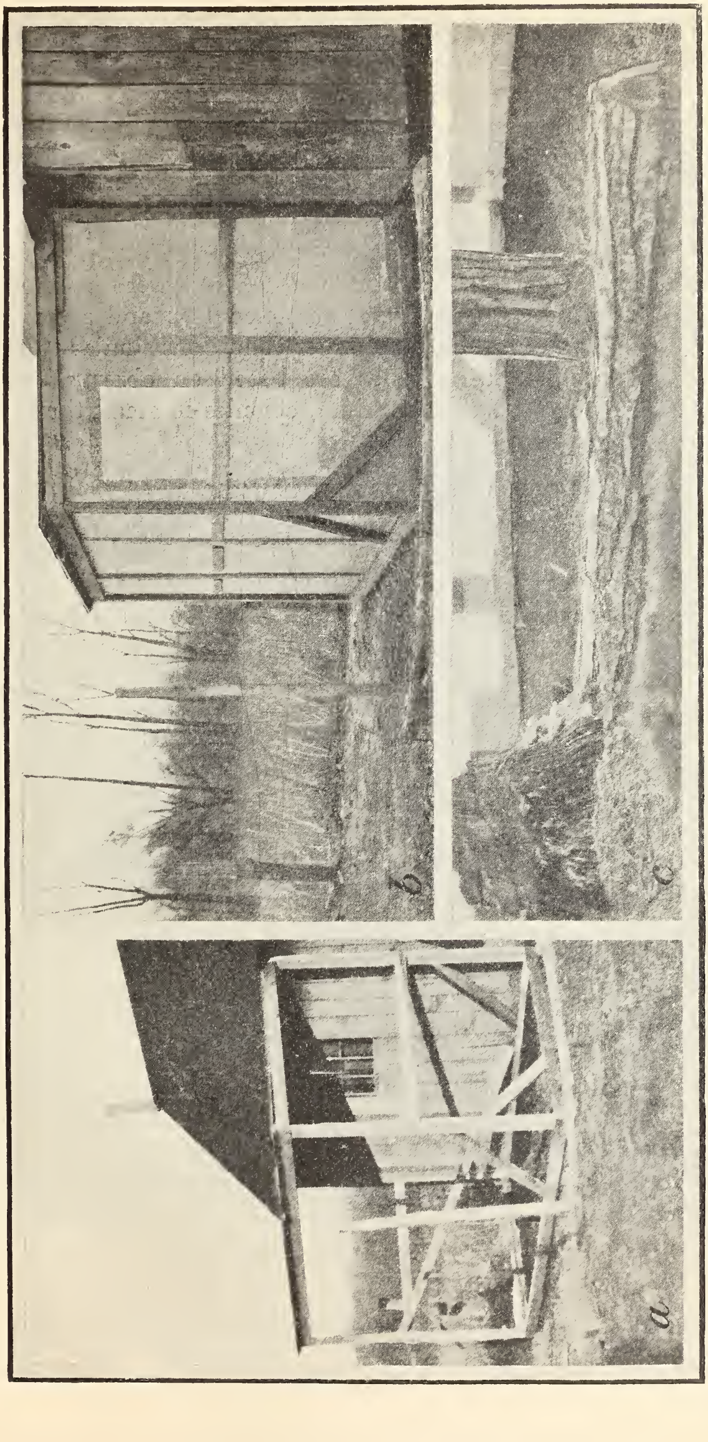


FIG. 5.—*a*, Unfinished termitarium showing iron bottom; *b*, finished termitarium; *c*, interior view of same termitarium showing infested log in foreground, infested stump, and trap logs. (Original.)

termitarium, after a careful examination to determine that no termites were already present. The earth in the cage was kept sufficiently moist in the endeavor, in so far as possible, to approximate natural conditions. (Fig. 5, *c*.)

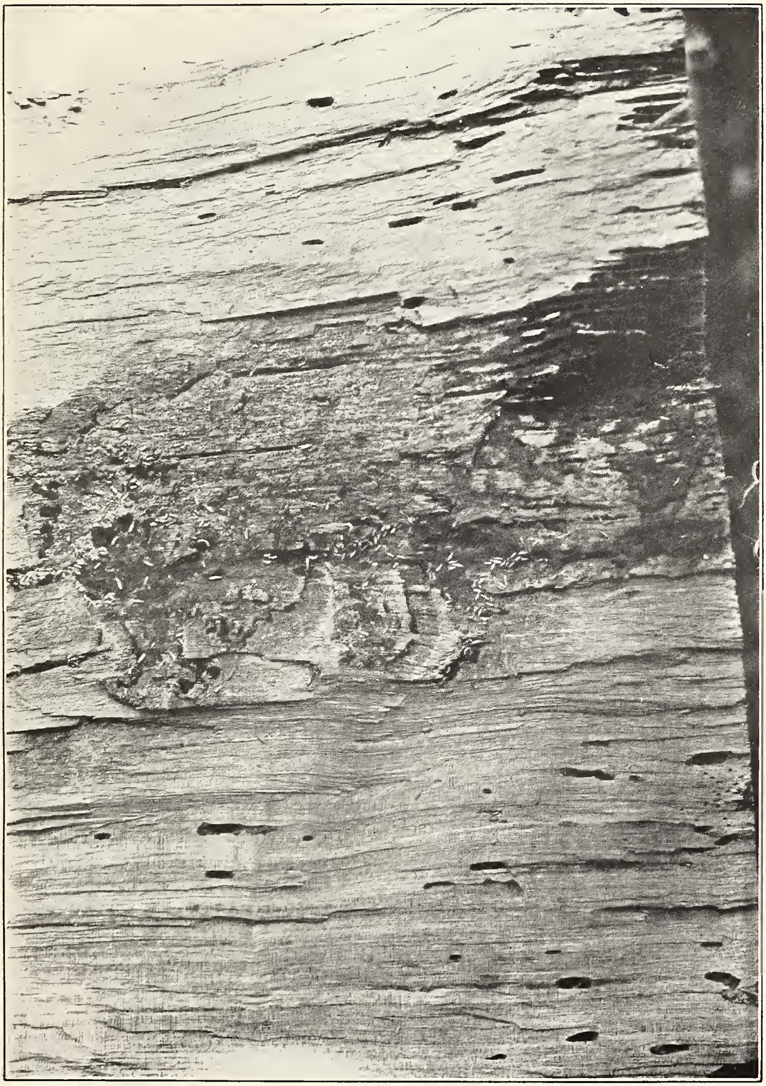
The termitarium was ready for occupancy on April 8, and a chestnut log infested with a colony of *Leucotermes flavipes* was introduced. This log had the bark on and was partially buried. On April 9 a decaying oak stump containing a colony of the same species was also placed in the cage and partially buried in the earth. Several termite colonies in logs and stumps in the forest were kept under observation at the same time, and seasoned logs and slabs with loosened bark were placed near by under conditions similar to those in the cage. The following notes are based on observations of colonies of termites in the termitarium, colonies in small tin boxes, and colonies in nature.

COMMUNAL ORGANIZATION.

SITUATION OF THE NESTS.

Termites in the eastern United States usually make their nests in decaying stumps or in logs and even small pieces of wood on the forest floor, although they also inhabit dead standing trees as well as injured living trees. They never form mounds as in the Tropics. These soft-bodied insects always conceal themselves within wood or in earth as means of protection against sunlight and their enemies, in consequence of which much of the damage they do is hidden. Termites of the genus Leucotermes are essentially wood destroyers and infest and seriously injure a great variety of crude and finished forest products which are in contact with the ground. The longitudinal excavations usually follow the grain of the wood,[a] and in the more sound wood their work is confined to the outer layers, where there is abundant moisture and incipient decay. A protective outer shell of wood is always left intact, since all except the winged, sexed, colonizing forms shun the light and are blind. Small, transverse, round tunnels which nearly pierce the outer shell are to be found when their tunnels closely approach the exterior. Sometimes the thickness of this protective shell is less than one-half millimeter. These may be soundings to see how nearly the surface is being approached, or merely unfinished excavations for the exit of the sexed adults, or possibly they may be feeding burrows. Termites often take advantage of the burrows of other wood-boring insects, enlarging and adapting them to their purposes; by these means they are

[a] Termite work can be readily distinguished from that of carpenter ants, whose excavations do not follow the grain. Sometimes in decayed wood, however, termites construct long, deep, but narrow, transverse galleries across the grain, forming ledges or shelves.

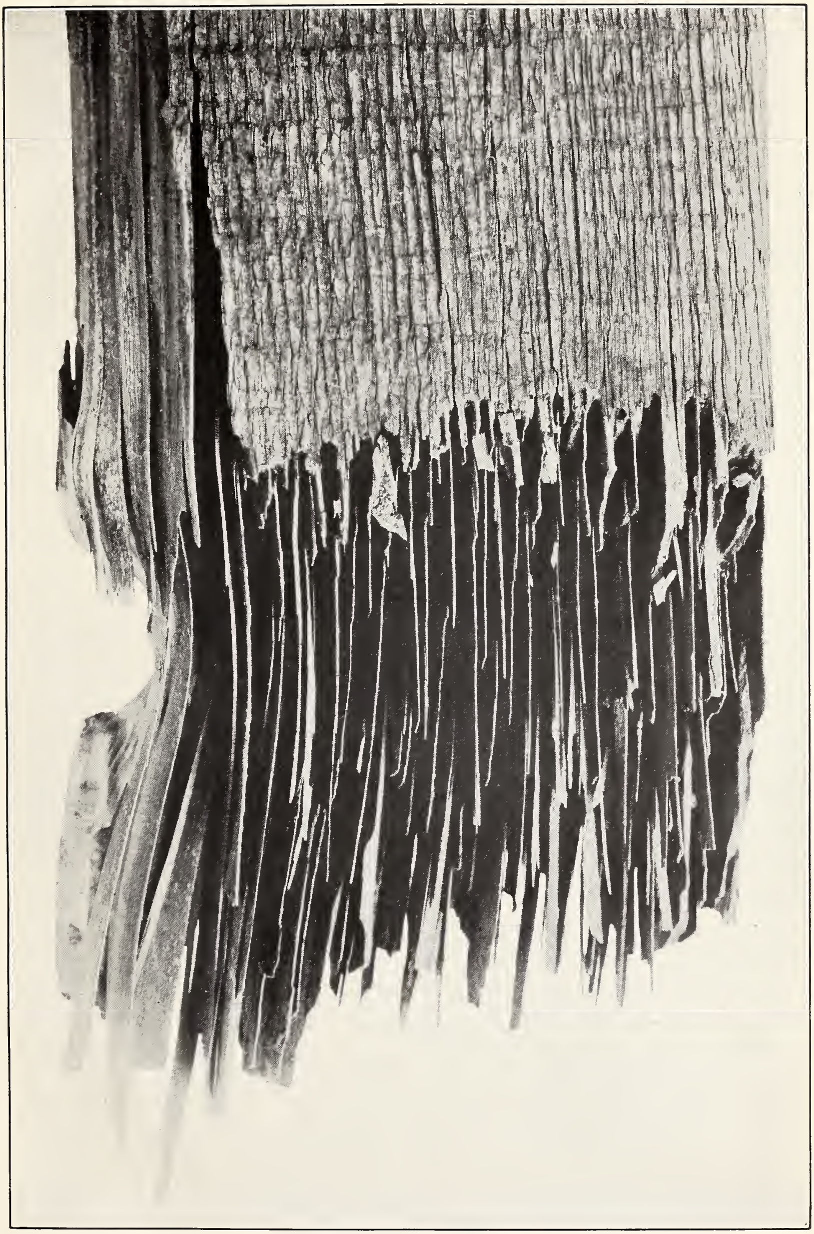


LEUCOTERMES VIRGINICUS.

All castes in heartwood of a maple tree infested by *Parandra brunnea*. (Original.)

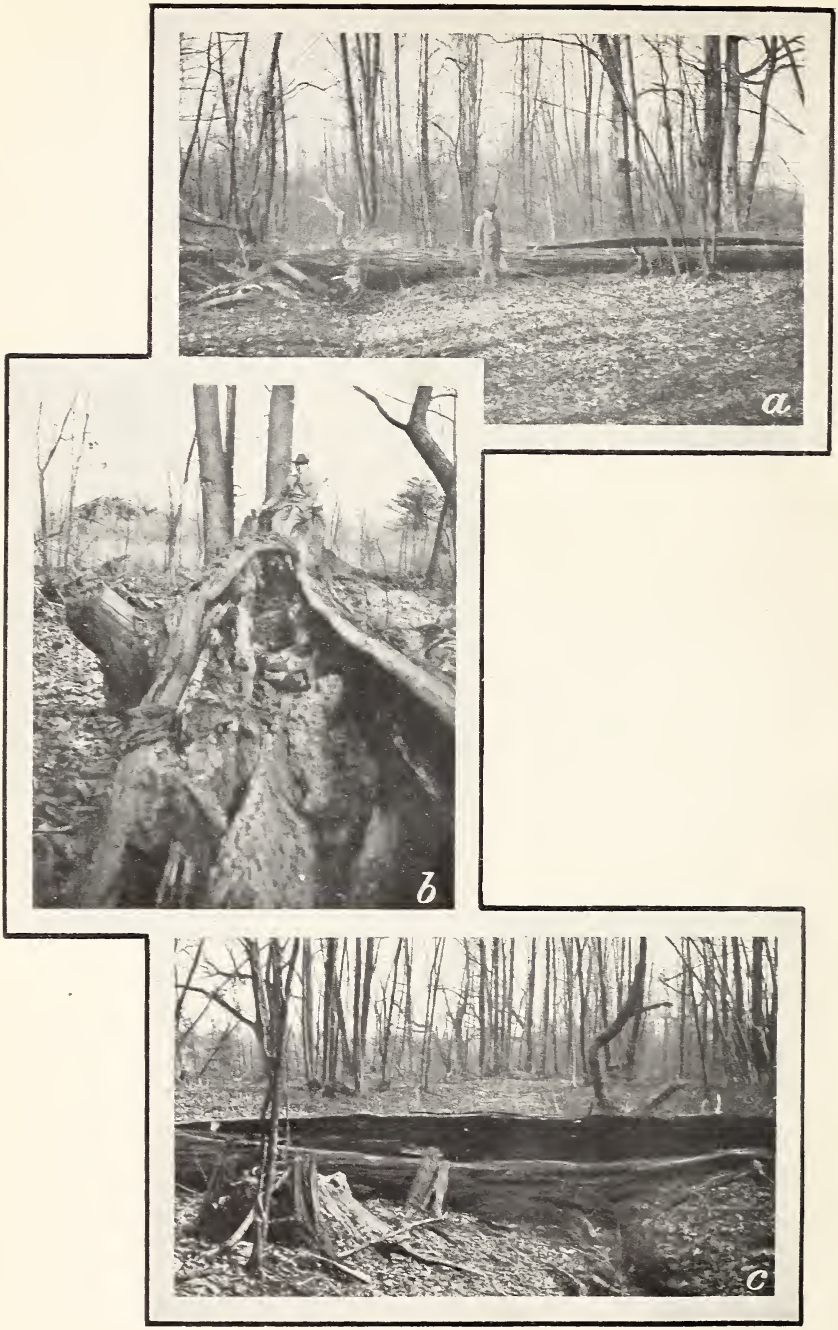
DAMAGE BY TERMITES.

A book destroyed by termites, Georgetown, D. C. (Photograph by W. S. Clime.)



DAMAGE BY TERMITES.

Pine barn sill cut into ribbons by *Leucotermes* sp. at Mayfield, Kans. (Original.)



DAMAGE BY TERMITES.

Living stag-headed chestnut tree, 50 feet in length, Falls Church, Va. *a*, Complete length of tree showing stag top and lightning scar on side; *b*, view of interior showing heartwood completely honeycombed; *c*, view of north side of tree showing width of scar, and honeycombed interior. (Original.)

able to penetrate more rapidly to the heartwood and honeycomb the interior.

Termites quickly disintegrate the wood of dead trees and stumps, which soon becomes converted to humus, the rapidity with which this is done depending on the relative resistance of the species of wood. This beneficial rôle in nature, however, is offset by the enormous destruction they accomplish in rapidly rendering insect, fire, and disease killed timber unmerchantable and by the damage they inflict to the roots and trunks of injured living trees. Termites will infest the heartwood of living trees injured at the base by fire, disease, or other insects (Pl. III), and sometimes in such trees they excavate upward, throughout the dead heartwood, longitudinal tunnels, irregular in diameter, the sides of which are lined with earth mixed with excrement. These insects also infest the roots of living trees, finding ingress through abandoned burrows of the large, roundheaded (Prionid) borers. Sometimes they girdle young trees—forest-tree nursery stock, for example—eventually cutting the trees off near the ground, examination disclosing that the stems were honeycombed. This is not necessarily due to the presence of dead wood near by, since termites will tunnel for long distances underground. While usually confining their work to moist or decaying timber or to vegetable material of any sort, and to books (Pl. IV) and papers that are somewhat moist, termites will attack seasoned, dry wood, provided there is access to moisture elsewhere; i. e., they use moist frass and earth in extending the burrows, thus creating more favorable conditions. In the Southern States termites will infest the bark and outer layers of the wood of the base of yellow pines killed by barkbeetles before the foliage has all fallen; trees that have been killed in the spring and show reddish-brown needles and much fallen foliage being infested by the middle of August. Trees killed in the spring will also have the outer layers of wood of the base honeycombed by the following December. (Fig. 6.) The larger-celled, thin-walled spring wood is eaten away first, leaving the smaller-celled, harder summer wood uneaten. (Pl. V.)

Where the heartwood is decayed in a standing living tree termites will work for a considerable distance above the ground, completely honeycombing the heartwood. In a living chestnut tree at Falls Church, Va., with the decayed heartwood exposed in a long scar, termites had infested the heartwood to a height of from 45 to 50 feet above the ground. The outer shell of living sapwood was intact. (Pl. VI.)

Termites are quite effective in clearing fields of old snags and stumps, but this benefit is offset by the damage they do to posts and buildings.

Termites (*Leucotermes* spp.) also inhabit subterranean passages. Drummond has compared tropical species of termites to earthworms and declared that they are equally as beneficial to man in aerating the soil. After swarming, many of the sexed adults excavate shallow cells in the earth under small pieces of decaying wood, and later enter the wood. The royal cell is constructed in decaying wood or in the earth slightly below the surface of the ground. Termites usually infest wood by entering from the ground underneath, rather than directly on the exposed surface, the latter being usually the habit at the time of the swarm. (*Termopsis angusticollis* Walk. usually infests wood by gaining ingress through wounds and abrasions.) None of the sound traplogs with loose bark in the termitarium or in the forest was infested except at the point of contact with the ground, but termites in pairs have been found under loose split bark on decaying logs where more moisture was present. Workers and soldiers are frequently to be found in the spring in small pieces of decaying wood lying on the ground, and termites probably extend old colonies or establish new colonies by means of subterranean tunnels. During the winter the members of the colony are to be found in a labyrinth of undergound passages.

FIG. 6.—Work of termites in insect-killed southern yellow pine. Tree killed in the spring; wood at base honeycombed by following December. Spartanburg, S. C. (Original.)

These excavations are of varying size and shape, and extend in all directions. Some of the tunnels are partitioned off into separate chambers, while others are unpartitioned runways. In the main runways the very young are absent. The partitions consist either of uneaten portions of the wood or small conical piles of moist earth mixed with frass (excreted, finely digested wood) of clay-like consistency. Sometimes in broad, shallow channels a small irregular mass nearly blocks the channel. The sides of the channels are smooth, and the uneaten masses of wood which serve as barricades appear as little islands and are distinct because of

the rough appearance due to the pores and cell walls of the wood. The walls of these channels are spotted with little piles of finely digested, excreted wood, giving the wood a characteristic mottled appearance.

Large cavities encountered by termites when working in the wood of logs, poles, or trees with decayed heartwood or hollow core are usually filled up with moist earth mixed with frass, the whole having a clay-like consistency and a conglomerate appearance due to the irregular deposits of excreted, finely digested wood. The "doty" hollow cores in the bases of infested poles are filled up in this manner.

In all their operations the termites carefully wall up and conceal themselves. Usually there is but little evidence on the exterior of infested wood to indicate the presence of termites, and they may not be detected until the interior is completely honeycombed. Sexed adults swarming from infested buildings are always a warning of their presence. Again, the outer surface is covered over with longitudinal viaducts of small diameter constructed of earth (Pl. VII, figs. 1 and 2), and whereas the interior channel is smooth, the exterior has a rough granular appearance. These viaducts are resorted to in order to extend the colony or to reach some object, such as decayed wood, or when their pathway crosses some impenetrable substance, the object, of course, being always protection from the light—all except the winged sexed adults shun the light—and their numerous enemies. Viaducts, or "sheds," can be seen running up to a considerable height above the ground in the longitudinal weathering checks on poles and posts, as well as between the crevices in the bark of infested dead and living trees, and uncovered viaducts are found under the loose bark on dead trees. Viaducts in the interior of hollow-cored poles or trees may be of large diameter and may consist of several irregular longitudinal interior channels.

Termites sometimes resort to another type of viaduct, which for descriptive purposes may be called suspended tubes. On May 26, 1912, at Elkins, W. Va., Dr. A. D. Hopkins found termite tubes of earth, 5 to 6 inches long, hanging from the end of a Virginia scrub pine sapling which had fallen, leaving the broken base 2 feet from the ground. The termites had evidently infested the base of the sapling through the ground before it fell and were trying to make connection with the ground by means of these suspended tubes. (Figs. 7 and 8.)

These covered viaducts or sheds, the uncovered viaducts, and the tubes—all constructed by termites of earth and excreted wood—are fragile.

NUMBER OF INDIVIDUALS IN COLONIES.

Young colonies of *Leucotermes flavipes*—that is, colonies but recently established, in decaying wood or in the ground under decaying wood, by sexed couples that have swarmed—are small, and since the rate of egg-laying by the young queens is remarkably slow, the

increase in numbers is also correspondingly slow. Observations of such incipient colonies in the spring of 1912 and 1913, after the swarm, the time of which varies with the season, from the middle of June to early July, indicate that from 6 to 12 eggs are normally to be found with pairs of *flavipes*. While the brood first hatched is relatively small, contrary to the habits in the other social insects coition is repeated and the young colony gradually increases in numbers.

On April 25, 1912, at Falls Church, Va., a small colony or subcolony of *Leucotermes flavipes*, the branch of a larger colony, was found under a small chestnut slab sunken in the ground. The day was warm and bright and many members of the colony were congre-

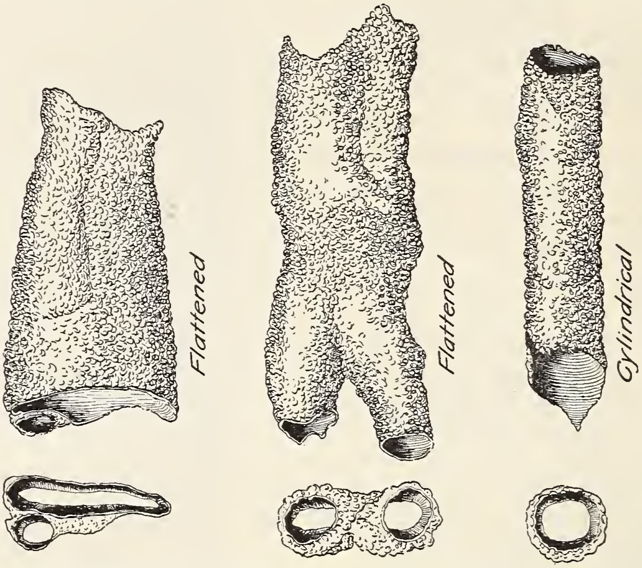
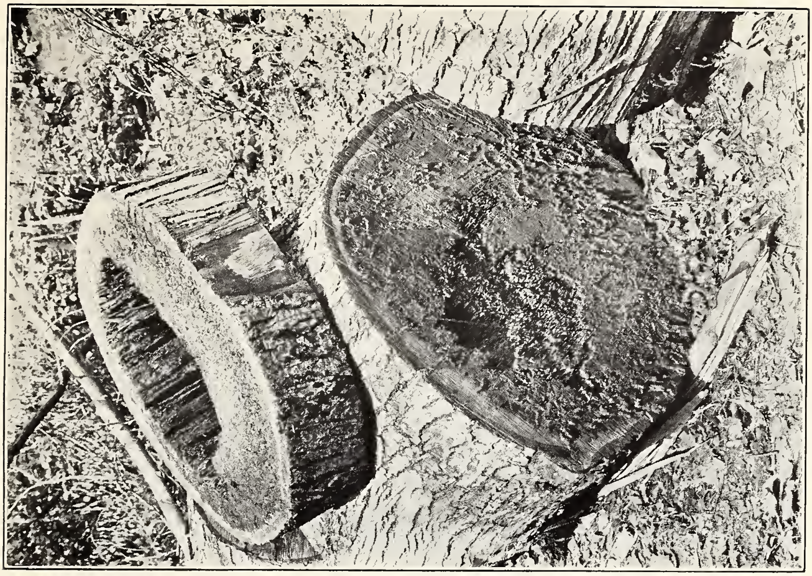


Fig. 7.—Suspended tubes, constructed by termites of earth and excreted wood. (Original.)

gated under the slab above ground. An attempt was made to capture the entire colony in order that the relative proportions of the various castes might be ascertained. Although nymphs of the first form constituted the most abundant caste, some few transforming nymphs and a few sexed adults were present, as well as a few workers and soldiers. Workers constituted the second most abundant caste. Nymphs of the second form appeared more active than the nymphs of the first form. The following possibly is not a fair statement, either of the number of individuals in the colony or the relative proportions of the different castes, since (1) the nymphs were probably above ground to take advantage of the warm afternoon sun which would aid their development—a common procedure; (2) only a few workers and soldiers were necessary to attend them and no doubt many more were still in the subterranean passages; (3)



WORK OF LEUCOTERMES VIRGINICUS.

Maple tree on Plummers Island, Md., infested by *Parandra brunnea* and by termites; showing sheds constructed by termites to cover up galleries exposed by sawing. (Original.)

many escaped and the workers would escape more easily than the nymphs; (4) probably, unconsciously, more effort was made to capture nymphs and soldiers than workers. The following figures, however, will probably approximate the relative abundance of castes. Nymphs of the first form, 279; nymphs of the second form, 86; nymphs of the first form in the quiescent stage, 31; individuals in the stage following, that is, with wings unfolded and held away from the body, 3; immature sexed adults without pigmentation, 17; immature sexed adults with gray pigmentation, 26; nearly mature adults, 5; nymphs of the second form molting, 4; workers, 93; soldiers, 24; the total being 568. Nymphs of the second form were only one-fourth as numerous as nymphs of the primary form, and, including all stages to sexed adults, gave a count of 90 to 361, respectively.

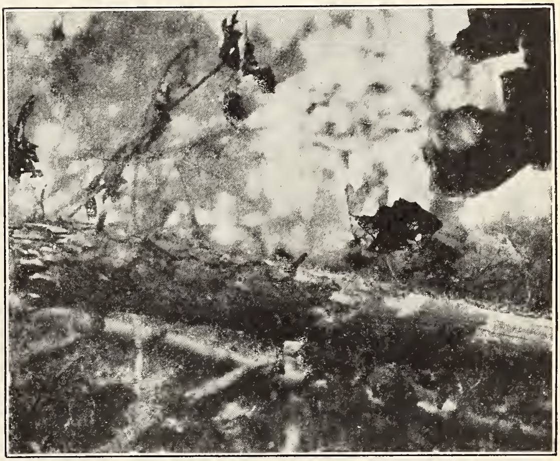


Fig. 8.—Broken-off pine sapling from basal end of which tubes in figure 7 were suspended by termites toward stump. (Original.)

On March 22, 1913, at Black Mountain, N. C., nymphs of the second form (*flavipes*) taken in a small decaying oak branch on the ground greatly outnumbered nymphs of the first form, although usually the latter is by far the more numerous form.

Due to the wandering habits of species of this genus, it is difficult to estimate the size and extent of an old, well-established colony, which may branch out over several acres of ground.[a] However, the number of individuals in well-established, permanent colonies probably runs up into the ten thousands, since from 5,000 to 10,000 (estimated) eggs, scatteringly or in clusters the size of a pea, were found in a large colony of *Leucotermes virginicus* near Chain Bridge, Va., on June 19, 1913. This colony, which was in a large decaying black oak log, consisted of a large number of workers and soldiers, and numerous larvæ.

THE DIFFERENT CASTES—POLYMORPHISM.

In a termite colony there are several different forms, or castes, of mature individuals, as well as those of different castes in the various stages of development. The castes are the workers, the soldiers, the

[a] The spreading out of a colony is largely due to increase in numbers and consequent need of fresh supply of food; that is, decaying wood.

colonizing winged adults of both sexes, the supplementary or neoteinic[a] reproductive forms (often in large numbers), both "ergatoids" and nymphal "neotenes," and the single true royal pair. Besides these mature forms there are freshly hatched, undifferentiated larvæ, differentiated larvæ, and nymphs of the first and second forms. Of course, all these forms are not present in a colony at the same time, as there is seasonal variation.

Workers are developed from larvæ that will not mature the sexual organs, but, unlike the bees, are of both sexes. They are dirty white in color, are large-headed and soft-bodied, with 10 segments to the abdomen, and at maturity are approximately 5 millimeters in length in *flavipes* and 3.5 millimeters in *virginicus*. The antennæ consist of 15 to 17 segments exclusive of the base in *flavipes* and 13 to 15 in *virginicus*. The workers constitute the most injurious wood-destroying form and have well-developed mandibles. The left mandible has five pointed teeth, the fifth tooth with a broad base, and the inner margin having parallel carinæ. The right mandible has two pointed teeth, the third and fourth teeth being broad, and the fourth with parallel carinæ. The mandibles evidently have both tearing and rasping functions. The labrum is rounded. The worker termites possess a large intestinal paunch and the contents enable the outline of this paunch to be seen through the tissue of the abdomen. Workers are blind.

Soldier termites (fig. 9, *a*) are more highly specialized workers, being also developed from large-headed workerlike larvæ that will not mature the sexual organs, and the caste is represented by both sexes. While they are soft-bodied, the head, which is pigmented yellowish-brown, is chitinized and is more oblong and elongate than in the worker, tapering slightly toward the apex, or being slightly broader at the base. The mandibles, which are enormously developed, are long, slender, saberlike, with no marginal teeth, chitinized, and of a yellowish-brown color. The body is of a dirty white or pale yellowish color. The labrum of the soldier is more narrow than that in the worker, elongate, and subelliptical. The "menton," which is chitinized, is convex, elongate, and more slender in comparison with the worker. Mature soldiers are from 6 to 7 millimeters in length in *flavipes* and 4.5 to 5 millimeters in length in *virginicus*. The antenna has from 14 to 17 segments in *flavipes* and 15 segments in *virginicus*. The soldiers, as well as the sexed adults, of these two

---

[a] Grassi, B., and Sandias, A. Op. cit., p. 249: "The term neoteinia has been introduced by Camerano (Bul. Soc. Ent. Ital. [v. 17], 1885, pp. 89–94) to denote the persistence during adult life of part or all of the characteristics normally peculiar to the immature, growing, or larval stages. * * * Neoteinia, or the persistence of larval characteristics, does not necessarily imply that anticipation of sexual maturity which is usually connoted with the use of the term pædogenesis, which, moreover, is strictly applied to agamic reproductions."

species can be differentiated. The soldiers, like the workers, are wingless and blind. Individuals of both castes complete their development in less than a year.

The nymphs of the reproductive form develop from larvæ that will mature the sexual organs. The term "nymph" is applicable,

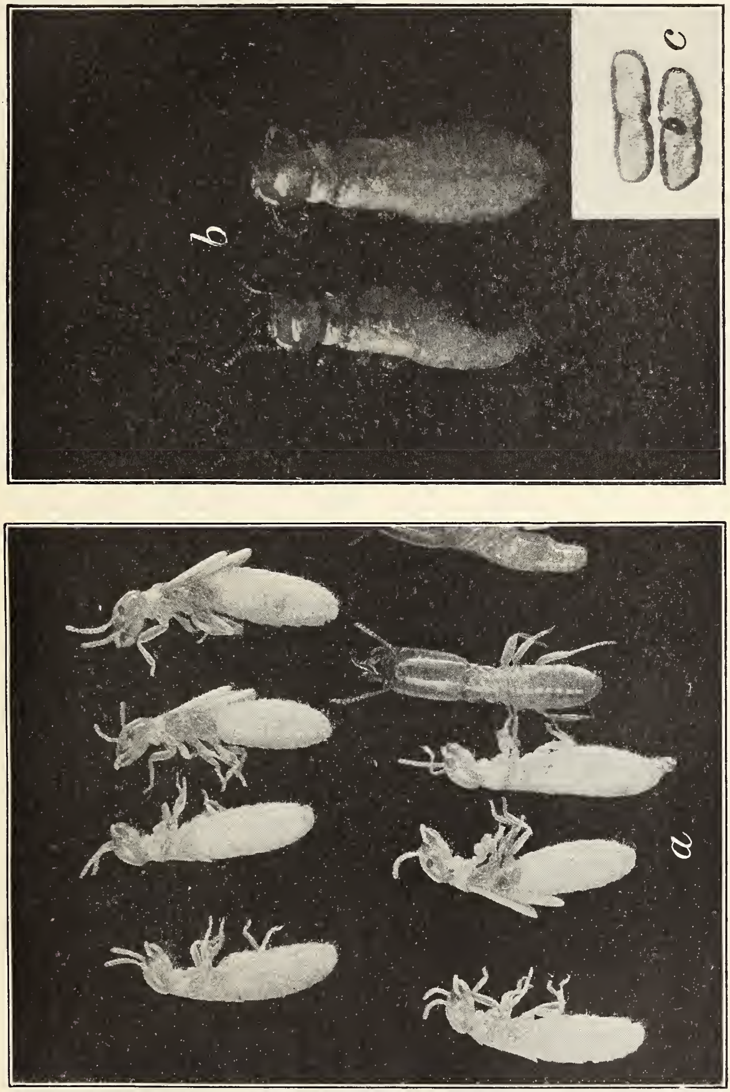


FIG. 9.—*Leucotermes virginicus*: *a*, Nymphs of the first form, and soldiers, Maryland, May 18, 1912; *b*, young nymphs, Maryland, May 18, 1912; *c*, view of brownish-black bands on dorsum of the abdomen of worker (enlarged 20 times); these bands occur on both *flavipes* and *virginicus*. (Original.)

according to Lespès and Hagen, to individuals "with the wing-rudiments easily distinguishable to the naked eye."[a] Individuals the wing-rudiments of which are present, but only distinguishable when under magnification, are termed larvæ. Nymphs are white

[a] Grassi, B., and Sandias, A. Op. cit., p. 264.

and soft-bodied, and when fully developed and ready to molt for the last time are from 7 to 7.5 millimeters in length in *flavipes* and 4.5 to 5 millimeters in *virginicus*. In *flavipes* the antenna consists of from 16 to 17 and in *virginicus* from 14 to 15 segments. The mandibles are practically the same as in the worker, and are probably very necessary in effecting an exit from the old colony. R. D. Grant states [a] that in a Missouri Pacific Railroad Co. engine house the rafters were injured and the cement of the brick walls built 14 years previously was perforated. Mr. C. L. Marlatt has specimens of plaster which was laid on metal lathing in a building at Charlotte, N. C., which had been mined in order to allow the winged adults to escape from heavy wooden beams which had been honeycombed. Also, in the establishment of the new colony the young royal couple have the excavating to do.

There are two forms of nymphs (Pl. VIII, figs. 3, *a*, *b*), namely, the primary form, with elongate wing pads, that develops into the winged sexed adult, and the "second form" (Lespès), with short wing pads—mere buds—which represents an arrested early stage of the nymph of the primary form, or even a larva. Nymphs of the secondary form are slightly more elongate, and develop the sexual organs without progressing further, instead of completing their normal development to the winged, pigmented, sexed adults that swarm. These nymphs, after becoming sexually mature and attaining a straw-colored pigmentation—normally after the nymphs of the primary form have developed to sexed adults—become supplementary royal individuals, kings, and queens, but never (?) leave the parent colony. They do not possess functional eyes.

The sexed individuals, when ready to swarm, are castaneous-black or light brown in color, have two pairs of long, filmy wings, and are so chitinized that they can bear full sunlight. They possess both functional compound eyes and simple eyes or ocelli. The body—excluding the wings, which are slightly longer than the entire insect and project some distance beyond the abdomen when "in situ"—is slightly less in length than in the case of the nymphs. The entire body of the sexed individual is from 9 to 10 millimeters in length in *flavipes* and from 7.5 to 8 millimeters in length in *virginicus*. There are from 16 to 18 segments to the antenna in *flavipes* and from 15 to 16 antennal segments in *virginicus*. The sexes are as easily distinguishable as in the case of fully developed nymphs. "(1) The seventh [abdominal sternite] (the apparent sixth) is strongly developed and semicircular, with the rounded edge posterior in the female and very short in the male. (2) The eighth sternite, which is reduced to two lateral lobes in the female, is small and entire in the male.

[a] Grant, R. D. Jour. Proc. Acad. Sci. St. Louis, v. 3, p. cclxix, November 19, 1877.

FIG. 1.—*a*, Lateral view of fully developed nymph of primary form; *b*, lateral view of neoteinic king—compound eyes without pigmentation.

FIG. 2.—Dorsal view of same: *a*, Showing pubescence and tapering abdomen of neoteinic king; *b*, nymph of the primary form.

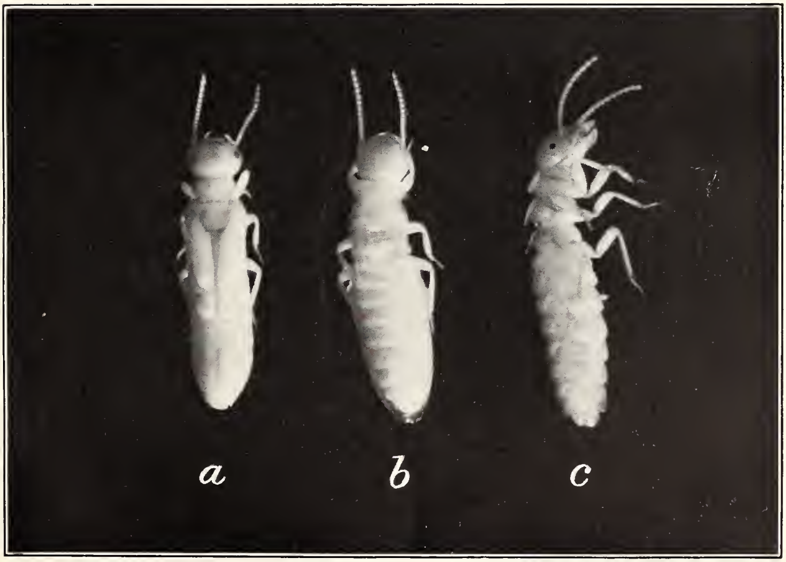


FIG. 3.—*a*, Fully developed nymph of the first form with elongate wing pads before final molt; *b*, nymph of the second form with short wing pads before final molt; *c*, neoteinic king after final nymphal molt. (Original.)

STAGES OF LEUCOTERMES FLAVIPES.

(3) The ninth sternite nearly resembles the eighth."[a] The genital "appendices" in the male are attached to "what is apparently the eighth, but is really the ninth sternite, the first being fused with the metasternum."[b] There are two segmented appendages, or cerci, attached to the abdomen. After swarming, the sexed adults become royal individuals.

Larvæ, or young, are undifferentiated individuals which, after further development, attaining chitinization and pigmentation, change to differentiated individuals. The larvæ, like all the other stages of termites, are active. When young or freshly molted the individuals are more transparent and white and the segmentation of the body at this stage is more sharply defined. "The younger the individual, or the more recent its ecdysis, the thinner is the chitin."[c] The term larva is applied (1) to any individual which has not yet attained full size, mature chitinization, and pigmentation; (2) in the case of the sexed individuals, to those with the wing-rudiments not easily distinguishable to the naked eye; and (3) in case of the soldier, to the large-headed, undifferentiated, workerlike forms.

The eggs are white, slightly reniform, and those laid by true queens (queens that have swarmed) are approximately 1 millimeter in length in *flavipes*. The eggs are usually found in clusters or scattered singly in the galleries.

THE SENSE ORGANS.

Termites are essentially subterranean in habit and in consequence all castes of Leucotermes are blind except the colonizing individuals. The soldiers have compound eyes, but without pigmentation; in some neoteinic royal individuals the pigmentation of the compound eye is not visible to the naked eye (Pl. VIII, fig. 2, *a*), but in most cases there is a slight pigmentation of variable intensity. All castes except the colonizing individuals shun the light.

Although blind, termites are known to possess other sense organs.[d] The antennæ are important tactile sense organs, and often individuals may be seen feeling their way by means of these appendages. The antennæ of the colonizing individuals are pitted, and from these pits, which appear as white depressions on the pigmented antennal segments, prominent hairs arise. A. C. Stokes, in an article entitled "The sense organs on the legs of *Termes flavipes* Koll.,"[e] describes

[a] Grassi, B., and Sandias, A. Op. cit., p. 306.

[b] Ibid., p. 271.

[c] Ibid., p. 256.

[d] Müller, Fritz. Beiträge zur kenntniss der Termiten. Jenaische Ztschr, Bd. 9 (n. F. Bd. 2), p. 241–264, pl. 10–13, Mai 8, 1875. See p. 254, pl. 12, figs. 32, 34.

[e] Stokes, Alfred C. The sense-organs on the legs of our white ants, *Termes flavipes* Koll. Science, v. 22, no. 563, p. 273–276, illus., November 17, 1893.

and figures "sensory hairs"; "sensory pits"; "tibial spurs with prominent basal apertures, across which extends a delicate membrane (auditory organs?)"; "pilose depressions"; "surface markings"; etc. Grassi [a] mentions tactile, "very long, fine, readily vibratile hairs" on the body, and states that the cerci also appear to be "essentially tactile." It is believed that there is a relation between the convulsive movements frequently observed, that is, the sudden jerking of the whole body, and these sense organs, and that individuals are thus enabled to communicate, or at least give danger or distress signals. The convulsive movements made by the workers and soldiers, when the royal pair are disturbed in the cell, are very violent and indicate great agitation.

There is a characteristic musty or acrid odor which can be easily detected in colonies of Leucotermes, and individuals frequently can be seen to follow directly in the path taken by others, but as termites usually travel in well-worn channels this may be due to tactile sense alone.

THE FUNCTIONS OF THE CASTES.

The social economy of termites is somewhat similar to that of other social insects, although in many respects totally different. Undifferentiated young hatch from the eggs, are active, and in turn transform to the differentiated individuals of the castes after a series of quiescent stages and molts.

As the name implies, the workers are those individuals that make the excavations, extend the colony, and care for and protect the royal couples and young.

The soldiers, more highly specialized workers, are of less importance functionally than the workers—just as the anther transformed to the petal in the common pond lily, *Castalia* sp., is less important functionally than the other anthers—yet both serve a purpose. Just before the time of swarming, the members of colonies become restless, and as the sexed adults emerge numerous workers and soldiers congregate on the outskirts of the colony near the exit holes with heads toward the exterior. The duty of the soldiers is apparently entirely protective, but they do not appear to be very effective, at least when the colony is opened and they are exposed to the attack of ants, etc.

The pigmented, winged, sexed adults, developed from nymphs of the first form, are the colonizing individuals which swarm in enormous numbers in the spring and found the new colonies, and when finally established at the head of a new colony, which they have reared, they become the royal couple. Unlike other social insects, the male continues to live, even after the fertilization of the female, and the king and queen inhabit the royal cell together, there

[a] Grassi, B., and Sandias, A. Op. cit., p. 267–269.

being repeated coition. Termites are sometimes polygamous, at least in incipient colonies. The young queens care for the young and carry the newly hatched larvæ in their mouths to safer places in the nest when the colonies are disturbed. (Nymphs of the first form also have been seen performing this duty in old colonies.) The workers attend the larvæ in old colonies.

In the life cycle of termites, however, there is so much variation in the development of the castes that it leads to a rather complex life history. Young are kept in a retarded, undifferentiated state and can speedily be turned into substitute reproductive forms of both sexes. These neoteinic royal individuals are used (1) as substitutes for the true royalty that have swarmed and (2) in splitting up the old colony into new and independent colonies. Fully developed nymphs of the second form are to be found in colonies in the spring. They never complete their normal development, which consists of the acquisition of wings and the mature pigmentation, but assume the characteristic pale straw color after the final molt. The sexual organs are developed after the acquisition of pigmentation. They become neoteinic reproductive forms, but always (?) remain in the parent colony.

Each caste has a distinct function, there being a well-defined division of labor, which, however, is not strictly adhered to. Termites properly represent the phenomenon of polymorphism, i. e., "species in which one or both of the sexes appear under two or more distinct forms,[a]" both sexes being equally polymorphic.

THE LIFE CYCLE.

THE METAMORPHOSIS—CASTE DIFFERENTIATION.

The metamorphosis of termites, while formerly considered to be a contrastingly simple type of insect development, is in reality very complex; indeed, there may be said to be different types of development for the castes. In the development of the worker, as in the order Thysanura, there is no external change or metamorphosis, the freshly hatched worker larva being active and of the same form as the adult worker. In the development of the soldier, however, marked changes in form occur, the mature soldier, with pigmented head and saberlike mandibles, being developed from a large-headed, white, workerlike larva (Pl. IX). The winged, pigmented, sexed adult is developed from a small-headed, white larva, there being a still more radical change. However, what may popularly be termed the "antlike" form can be distinguished in all stages in the development of all the castes, hence termites can hardly be classed with insects with "complete metamorphosis' as the true ants, where there

[a] Wheeler, W. M. Concerning the polymorphism of ants. Bul. Amer. Mus. Nat. Hist., v. 23, p. 50–93, 6 pls., January, 1907. See p. 50.

are the three successive stages of larva, pupa, and adult, although termites pass through pupalike "quiescent" stages in the molting of larvæ and nymphs, with temporary periods of inactivity. Furthermore, great variation is possible in the metamorphosis, as is seen in the development of "neoteinic" or "supplementary" reproductive forms, as the "neotenes" and "ergatoids." Therefore, in general, termites may be classed with insects having "incomplete metamorphosis," as the locusts and roaches. In this type of development the form of the body is always essentially the same as that of the adults. The development of the larva and nymph to the winged sexed adult termite greatly resembles the development of the locusts and roaches.

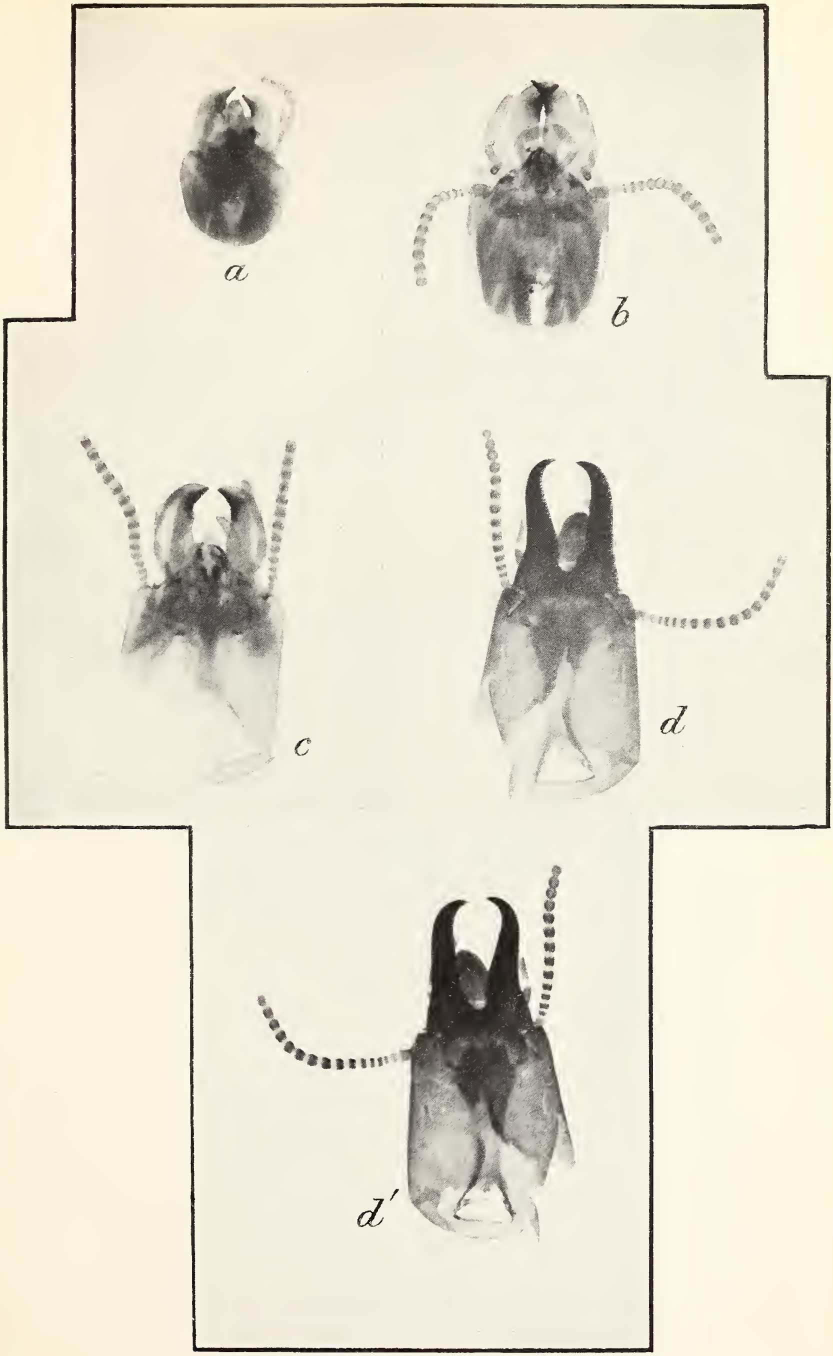
In the genus Leucotermes there is no apparent metamorphosis in the case of individuals of the worker caste. The freshly hatched worker larva is active, there being a very simple development. The

FIG. 10.—*Leucotermes flavipes:* Quiescent stage of molting larvæ. Enlarged 10 times. (Original.)

change from larva to adult is a gradual growth, the white, large-headed larva passing through a series of quiescent stages and molts. The adult worker is of a dirty grayish-white color. In the soldier caste and the reproductive forms the metamorphosis is more complicated, and marked changes in form occur during the development. Young molting larvæ in the "quiescent stage" [a] were first observed by the writer on August 11, 1911, near Jerseyville, Ill., in a large, wide, longitudinal channel in the decaying heartwood of the butt of a white cedar telegraph pole.[b] Previous to the molt the larva falls over on its side and passes through a quiescent stage, the head being bent down to lie on the ventral side of the body along which the antennæ and legs, also, lie extended in a backward direction. This gives the larva the appearance of being doubled up (fig. 10). After the skin has been shed the larva resumes its normal activity.

[a] Strickland, E. H. Loc. cit.

[b] Snyder, T. E. Changes during quiescent stages in the metamorphosis of termites. Science, n. s., vol. 38, No. 979, pp. 487–488, October 3, 1913.



LEUCOTERMES VIRGINICUS AND L. FLAVIPES.

Molting soldier nymphs: *a*, *L. virginicus*, head showing mandibles and labrum of soldier nymph just molted from workerlike larval form; *b*, *L. flavipes*, same at later molt; *c*, *L. flavipes*, same at later molt; *d*, *L. flavipes*, mature soldier; *d′*, ventral view showing convex, slender, chitinized, pigmented "menton." Photograph from specimens in balsam slides. Enlarged 16 times. (Original.)

The antennæ increase in the number of segments by the subequal division of the third segment [a] independent of the molts in *L. lucifugus* Rossi.

In the metamorphosis of the soldier, as has been shown by Grassi [a] (*Calotermes flavicollis* Fabricius and *Leucotermes lucifugus* Rossi), Knower [b] (*Eutermes* sp.), and Heath [b] (*Termopsis angusticollis* Walker), there is a radical change from a large-headed larva to the soldier caste. This change takes place during [c] a quiescent stage. The worker, like the soldier, also develops from a large-headed larva; that is, in the colony there are two types of larvæ, the large-headed and small-headed, the former normally developing to workers and soldiers, while the latter become the reproductive forms. According to Grassi there are four molts in the development of the asexual forms of *Leucotermes lucifugus*, whereas the sexed forms pass through five molts. Holmgren states [d] that in Leucotermes the soldiers are polymorphic and originate [e] from at least five different larval stages, while the polymorphic workers originate from three different larval forms. The undifferentiated larvæ present possibilities of development in all directions, but the development of Leucotermes shows that the breeding possibilities, while great, are by no means so great as in Calotermes. This would indicate progressive development toward stability, as is also indicated by the absence or rarity of neotenes and ergatoids in the more highly developed termites (Termes and Euter-

[a] Grassi, B., and Sandias, A. Op. cit., p. 270.

[b] Op. cit.

[c] Snyder, T. E. Loc. cit.

[d] Holmgren, N. Termitenstudien 3. Systematik der Termiten—Die Familie Metatermitidæ. K. Svenska Vetensk. Akad. Handl., Bd. 48, No. 4, pp. 166, 4 pls., Uppsala and Stockholm, 1912. Blick auf dem mutmasslichen, stammesgeschichtlichen Entwicklungsverlauf der Termiten, p. 129–153.

[e] The recent discovery by McClung, Stevens, and Wilson (Wilson, E. B., Heredity and miscroscopical research: Science n. s., v. 37, No. 961, p. 814–826, May 30, 1913) of the association of an odd number of chromosomes, in the divisions of the spermatocytes—that is, cells formed by the division of the "spermospore," the male germinal cell—with the determination of sex may also be applicable to caste differentiation in termites. Wheeler (Wheeler, W. M., The polymorphism of ants, with an account of some singular abnormalities due to parasitism: Bul. Amer. Mus. Nat. Hist., v. 23, p. 1–93, pls. 6, Jan., 1907), however, states, with reference to ants, that nourishment, temperature, and other environmental factors merely furnish the conditions for the attainment of characters predetermined by heredity, that is, with Weismann he believes that the characters that enable us to differentiate the castes must be represented in the egg, but with Emery he believes the adult characters to be represented in the germ as dynamic potencies or tensions rather than morphological or chemical determinants. Holmgren states (op. cit., p. 140) that in termites, as the result of the method of feeding, three potential germ plasms are released in at least three directions * * * and that there must be a germ plasm correlation which finds its expression in the caste correlation.

mes), wherein, however, there may be several true queens [a] in the one colony and where polygamy exists. In insects supposed to represent the most primitive, or lowest and least developed, types this is a rather complex metamorphosis. Here also there is much variation in the life cycle and no strict rule is followed. (See chart.) Apparently the individual development is entirely subservient to the needs of the colony. This ability of adaptation of individual to circumstance leads to a complex economy.

A representation [1] *of some of the successive stages in the development of the various forms or castes in the life cycle of Leucotermes flavipes Kollar as found in colonies in the eastern United States. All these reproductive forms are not present in the same colony at the same time.*

Eggs.

(A) (1) Young, undifferentiated larvæ.

(B) (2) Large-headed larvæ that will not mature sexual organs. (3) Larvæ that will mature sexual organs. (4) Reserves for emergency reproductive forms.

(C) (5) Larvæ of soldiers. (6) Larvæ of workers. (9) Nymphs of the first form with long wing pads. (10) Nymphs of second form (Lespès) with short wing pads. (11) Reserves for emergency reproductive forms.

(D) (7) Soldiers. (8) Workers. (12) Winged, pigmented, sexed adults.

(13) The true royal pair, with wing stubs. (14) Nymphal neoteinic substitute reproductive forms. (15) Nymphal emergency substitute reproductive forms. (16) Larval emergency substitute reproductive forms.

[1] See correlated forms of *Leucotermes lucifugus* Rossi. Grassi, B., Ein weiterer Beitrag zur Kenntnis des Termitenreiches. Zool. Anz, Bd. 12, No. 311, pp. 355–361, July 8, 1889. Übersicht der im Termitenstaate vorkommenden Formen- *Termes lucifugus*, p. 360); id., Ein weiterer Beitrag zur kenntniss der Termitenreiches. Ent. Nachr., Jahrg. 15, No. 14, pp. 213–219, July, 1889; Holmgren, N., Termitenstudien 3. Systematik der Termiten- Die Familie Metatermitidæ. K. Svenska Vetensk. Akad. Handl., Bd. 48, No. 4, p. 148, Scheme B, Uppsala & Stockholm, 1912 (table showing parallel evolution and at what molts changes or development occur).

PROGRESSIVE DEVELOPMENT OF THE NYMPHS.

Colonies of *Leucotermes* spp. in the northeastern United States are dormant during the winter, the insects retiring to the more remote

[a] John, O. Notes on some termites from Ceylon. Spolia Zeylanica, v. 9, pt. 34, p. 102–116, 1913.

Riley, C. V. Termite economy. Proc. Biol. Soc., Wash., v. 9, p. 71–74, April, 1894.

Escherich, K. Termitenleben auf Ceylon, Jena, 1911, p. 45–46.

galleries in the wood or to the subterranean passages of the nests, At Falls Church, Va., in 1912 it was not until March 11, in 1913. February 20, and in 1914, March 23 that signs of activity were observed in colonies of *flavipes*. Nymphs of the first form with "short wings" (Fritz Müller) or "wing pads" (Hagen) were present on March 11, 1912. At this time the wing pads were well developed, being about two and one-half times the length of the segment from which they originated, and had a yellowish tinge. The antennæ consisted of from 16 to 17 segments, excluding the base, and the line of demarcation between the basal segments was less distinct. On March 29, 1912, the ocelli were visible in the nymphs; antennæ, head, and thorax were acquiring a tinge of yellowish-brown, and the compound eyes were becoming pigmented—a reddish-brown. On April 18, 1912, and April 8, 1913, at Falls Church, Va., nymphs of the first form when fully developed and ready for the final molt could be readily distinguished by the opaqueness of the elongated wing pads, the filmy, yellowish-brown, loosening skin, which becomes separated from the body, particularly posteriorly, and the reddish-brown pigmentation to the compound eyes. (Pl. VIII, fig. 1, *a*.) The nymphs gradually increase in size and pass through a series of molts and quiescent stages until the final molt, when the wings are unfolded. Packard, who figures [a] the stages in the growth of the wing in *flavipes*, states that the wings are simply expansions. During the latter part of April, 1912, nymphs with short wing pads, or those of the second form (Lespès) (Pl. VIII, fig. 3, *b*), were found in colonies. Their antennæ had from 16 to 17 segments. These nymphs appear to be more active than nymphs of the first form and have but slight pigmentation of the compound eye.

During the final molt—which occurred from April 18 to 27, 1912, April 8 to 17, 1913, and April 22 to May 2, 1914, at Falls Church, Va., in case of the nymphs of the first form (*flavipes*)—nymphs of both the first and second forms pass through a "quiescent stage" [b] (Pls. X and XI), which closely approaches the pupal stage of insects with complete metamorphosis. This quiescent stage apparently serves the same purpose as the pupal stage, since the most marked changes, both external and internal, take place during this molt; it is, however, of short duration. On April 18, 1912, the first nymphs (*flavipes*) in this stage were observed in the outer layers [c] of a decaying stump. All of the nymphs in this colony were fully developed, but very few had

---

[a] Packard, A. S. A textbook of entomology. New York, 1903, p. 140.

[b] Strickland, E. H. Loc. cit.

[c] Larvæ or nymphs in the quiescent state are usually to be found isolated in small but deep, transverse conical nitches or shelves in the nest where they are not liable to disturbance by the movements of the other members of the colony. Possibly they seek out such secluded places, usually near the outlying galleries, beforehand, or may be carried there while helpless, by the workers. Clusters of eggs are also found in similar nitches.

yet begun to molt. A large number were placed in a covered tin box $3\frac{1}{2}$ by 5 by $1\frac{1}{2}$ inches, with disintegrated wood and moist earth in the bottom. This was to be a check box, and the conditions here were more natural than in the small corked vials, in which over 100 other nymphs had been kept in the dark, one nymph to each vial. The development of each nymph was watched and the time necessary for the various changes from nymph to adult was noted. On June 8 fully developed nymphs of *virginicus*, with opaque wing pads, were observed to molt in a similar manner. Nymphs in all stages described for *flavipes* were observed molting until June 11.

As E. H. Strickland has already figured and described these changes in the nymphs of the first form (*flavipes*), his accurate description is here quoted in detail, with a few comments. Until this description appeared, the quiescent stage in the development from nymph to adult for this species was undescribed. His observations were made from nymphs collected in the neighborhood of Boston, Mass., May 7, 1910.

The mature nymph becomes very sluggish and finally all movement ceases; it then falls over on its side and the head is bent down till it lies on the ventral side of the body, along which also the antennæ and legs are extended in a backward direction, * * * while the wing pads are bent downward till they lie laterally along the sides of the body. * * * It will be at once noticed that while in this position the nymph is to all appearances a quiescent "pupa libera." There does not appear to be an ecdysis immediately prior to this quiescent period, however, so I would hesitate to describe it as a true pupal state though it undoubtedly has the same physiological function.

This quiescent stage lasted in the few specimens observed for a period varying from four to about nine hours.[a] The duration in time seems to be controlled to a large extent by the amount of moisture in the earth surrounding the pupa for when specimens were placed in perfectly dry earth they were unable to pass beyond this stage of development,[b] while the greater the amount of moisture, the shorter the period. During this stage the last nymphal skin splits across the head and along the dorsum, and is slowly worked downward and backward till a large portion of it hangs freely from the apex of the abdomen on the ventral side. The legs are the last part[c] of the body to be freed from this skin, which then becomes detached as a much crumpled mass. As soon as the wings are liberated they begin to move away from the body at their base. This is apparently due to the tracheæ in the basal portion of the wing becoming inflated. The inflation, however, does not extend beyond the suture along which the wing is subsequently broken off, and the distal portion remains tightly folded. * * *

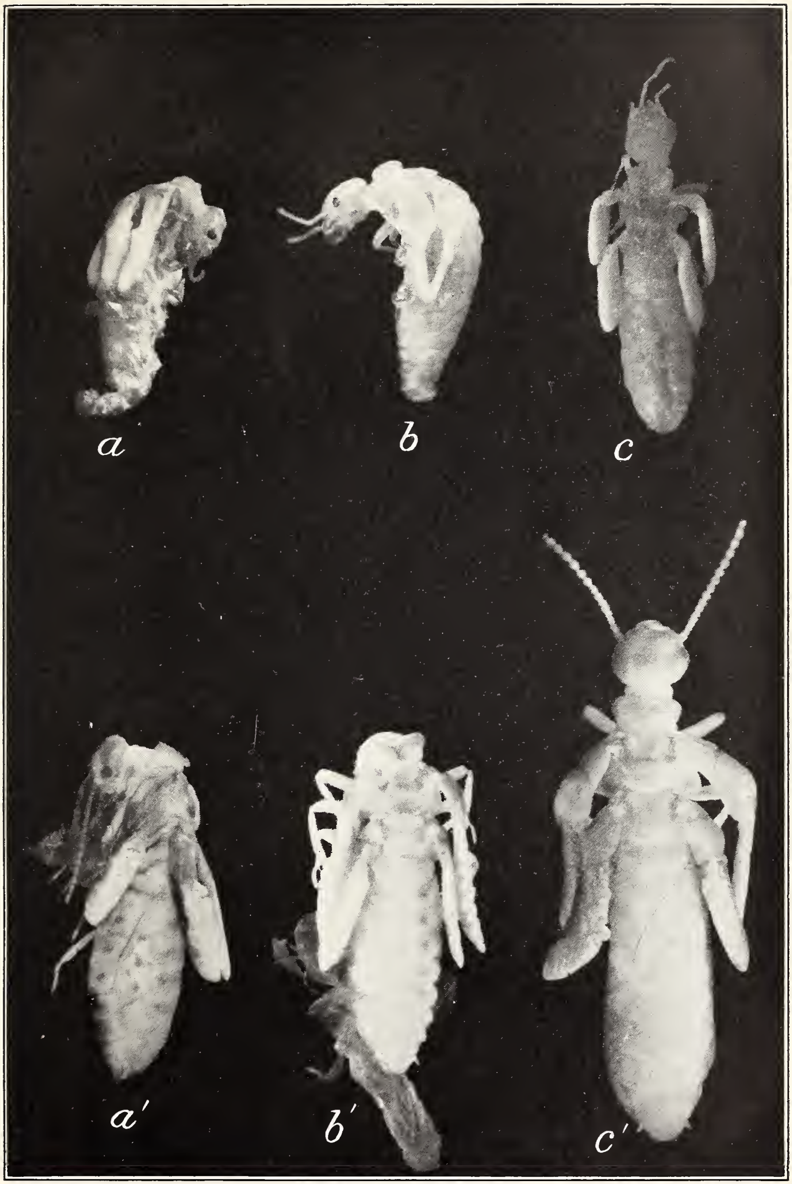
The ecdysis described above is the last in the development of the imago, for the insect now disclosed is the sexually complete[d] adult; it does not, however, become

[a] Varying from about $3\frac{1}{2}$ to 12 hours at Falls Church, Va.—T. E. S.

[b] A considerable amount of moisture apparently is essential to normal development. Specimens placed in small, individual, corked vials molted normally, while others placed in vials the mouths of which were lightly plugged with cotton developed abnormally, with distortions, or not at all.—T. E. S.

[c] Sometimes the antennæ are the last part to be freed of the cast skin in case of nymphs of both the first and second forms.—T. E. S.

[d] At this stage the sexual organs are not yet fully functionally matured.—T. E. S.



LEUCOTERMES FLAVIPES.

a and *b*, Lateral views of the quiescent stage of nymphs of first form; *c*, dorsal view of active molted nymph showing how wings are held away from the body. Photographs from etherized specimens. *a′*, Lateral view of quiescent stage of nymphs of the first form (skin cast); *b′*, dorsal view of same; *c′*, active molted nymph of first form with wings unfolding. From alcoholic specimens. (Original.)

LEUCOTERMES FLAVIPES.

a, Quiescent stage of molting female nymph of second form; *b*, molted male nymph of second form or neoteinic king—cast skin still attached to legs; *c*, mature neoteinic king not sexually mature and just molted. (Original.)

active as soon as it emerges but remains for about a quarter of an hour in the same position as that in which the ecdysis occurred. During this time, however, the head is slowly drawn upward to its normal position and the insect finally struggles to its feet. Its movements are at first very awkward and uncertain but after a few minutes it is actively running about. As before mentioned, the greater portion of the wings remains closely folded together so that at first sight they appear as abnormally placed wing-pads. A close examination with a hand lens shows them to consist of the very compactly folded wing. * * *

After these young adults have been running about for an hour or so the main portion of the wing begins to expand; the basal portion becomes expanded before the apical part begins to unfold, but the inflation gradually works toward the apex till the typical fully winged though pigmentless adult is produced. The wings continue to be held away from the body till this process is complete, after which they are folded from the base in an overlapping position over the abdomen. The ensuing pigmentation of the body is gradual[a] and does not appear to be affected by the presence or absence of light; the entire body turns black through shades of yellow and brown till in about twenty-four hours the sexually complete imago is ready for swarming.

It will be seen that the whole period intervening between the normal nymphal stage and the typical pigmentless adult stage[b] occupies only some nine to ten hours, and this apparently accounts for its not having been recorded before, even though it appears to be perfectly normal,[c] for it has occurred in different localities in two successive years and all nymphs taken passed through these stages before completing their development.

An illustration of the thorax of *Leucotermes flavipes* with unexpanded wings was given by Packard in his Text-book of Entomology, but he here described it as a late nymphal wing pad, otherwise there seem to be no references to either of the stages herein figured and described.

FIG. 11.—*Termopsis angusticollis:* Quiescent stage of nymph of the first form. Enlarged 7 times. (Original.)

[a] The borders of the chitinized parts first take on pigmentation, passing through shades of gray to castaneous to the castaneous-black of the mature adult, the abdomen being the last to take on pigmentation; there are often abnormalities in development.—T. E. S.

[b] The whole period intervening between the fully developed nymph and the mature pigmented adult is about one day and one-half to two days for individuals, and about 1 week to 10 days for the colonies.—T. E. S.

[c] These stages are absolutely normal and necessary to the progressive development of nymphs of species of both the genera Leucotermes (*L. flavipes* and *virginicus*) and Termopsis (*angusticollis*) (fig. 11).—T. E. S.

During this final molt the females of nymphs of both the first and second forms normally lose the genital appendices;[a] that is, the genital appendices are present in nymphs of both sexes before this molt, but afterwards only in mature winged males and supplementary kings, developed from nymphs of the second form; these appendices can be readily seen on the cast skins. In egg laying complementary queens of *Termopsis angusticollis* (with no indication of wing pads), genital appendices were present, though absent in true queens.

On April 25, 1912, at Falls Church, Va., molting nymphs (*flavipes*) of the second form were found. The progressive development of over 100 nymphs was noted, and apparently the molting is similar to that of nymphs of the first form. Before the quiescent stage is reached, the nymphs assume a straw-colored hue. Various stages of molting nymphs were observed through April 28. After the molt, the head and prothoracic segments darken, especially on the borders. The abdominal segments also darken. Sometimes there are grayish-black, longitudinal, pigmented markings on the head. Some of the nymphs have very short wing pads, mere buds, while in others the wing pads are more elongate, the pair on the metathorax reaching down to and slightly overlapping the (apparent) second abdominal tergite. This difference can be seen in supplementary or neoteinic reproductive forms and illustrates the fact that the growth of nymphs of the first form is arrested in various stages of development, as does (?) the presence of genital appendices in complementary queens of *Termopsis*.

Sometimes, due to unfavorable moisture conditions, there is an abnormal development of nymphs of the first form. Individuals may be observed with partial pigmentation to the chitinized parts, acquired before the quiescent stage or before the wings are unfolded; that is, the wings may be in various stages of development, from the opaque-colored, elongate wing pads to partially unfolded, or unfolded but still crumpled, wings. There is great individual variation in the manner of molting. Adults with mature body pigmentation but with distorted, poorly developed wings, or even with opaque wing pads, have been observed emerging from the parent colony at swarming time. A swarm[b] of *flavipes* occurred at Falls Church, Va., on May 8, 1912, and another on April 25, 1913, while in the case of *virginicus* the swarm occurred on June 1, 1913.

This quiescent stage, or "Ruhestadium," has been described by Hagen.[c] He states (in regard to the final molt of nymphs of the first form) that the skin bursts on the prothorax; and in order to

---

[a] Grassi and Sandias. Op. cit., p. 306.

[b] It is from 7 to 10 days after the last sexed adults in colonies have acquired wings and mature pigmentation that the swarm occurs.

[c] Hagen, H. A. Monographie der Termiten. Linnaea Entomologica, v. 12, p. 337–338, 1858.

get out of the old skin, the insect doubles up. The insect lies on the ground during the molt. Grassi, while he did not describe this stage, knew that during certain ecdyses in the development of nymphs and soldiers important changes took place. Odenbach, January 13 to 24, 1896, observed in an artificial nest indoors (manuscript notes) molting larvæ of *flavipes* in the quiescent stage, as if dead. He states that the molting process lasts three and one-half hours, that workers assisted, and that the skin is eaten. His observations are practically the same as those of Strickland. Holmgren describes this stage in the larva of *Rhinotermes taurus* Desneux, Escherich[a] figures larvæ of *Termes obscuripes* Wasmann, and Bugnion[b] figures a soldier of *Termes horni* Wasmann in this quiescent stage. Holmgren was the first to state that a quiescent stage occurs in connection with each molt, and to note the internal as well as external changes that occur during these molts.

The writer has observed quiescent stages of undifferentiated (?) larvæ, larvæ of nymphs of the first form, nymphs of the first and second forms, and larvæ of workers and soldiers of *Leucotermes flavipes* and *L. virginicus* and soldiers and nymphs of the first form of *Termopsis angusticollis*.[c] Differentiated nymphs of the first form of *L. virginicus* only 2.5 mm. in length have been observed. Bugnion states[d] that since he has found nasuti larvæ of *Eutermes lacustris* Bugnion 1.3 mm. in length he believes that the differentiation is effected in the embryo for the three castes. The young nasutus with the distinct "corne frontale" is figured. This is not at all in accordance with Knower's statements and drawings of the development of the nasutus of Eutermes (rippertii?) which developed from a worker-like larva, and with Grassi's description in *Calotermes flavicollis* Fabricius and *Leucotermes lucifugus* and the writer's description in *L. virginicus* of the development of soldiers from worker-like larvæ. Bugnion further states[e] that in the higher termites the differentiation of caste reaches perfect expression.

Observations by the writer of molting soldier larvæ of *Leucotermes* spp. show that the differentiation takes place during a "quiescent stage" rather late in the life cycle.

From the first to the middle of August, 1913, freshly molted pigmentless soldier nymphs of *flavipes* in the stage preceding maturity were noticeable in colonies in Virginia. From the middle of June

---

[a] Escherich, K. Op. cit., p. 43.

[b] Bugnion, E. Le Termes Horni Wasm. de Ceylan. Rev. Suisse Zool., t. 21, no. 10, p. 299–330, pl. 11–13, juin, 1913. See p. 305–309.

[c] Snyder, T. E. Loc. cit.

[d] Bugnion, E. Les termites de Ceylan. Le Globe: Memoires Soc. Geog. Geneva, t. 52, p. 24–58, 1913.

[e] Bugnion, E. La differenciation des castes chez les Termites [Nevr.]. Bul. Soc. Ent. de France, 1913, no. 8, p. 213–218, April 23, 1913. See p. 217.

to the first part of July, 1914, molting large-headed soldier larvæ and nymphs of *Leucotermes flavipes* were found in colonies in Virginia. After the first part of July freshly molted, pigmentless nymphs of soldiers were common in colonies. On August 17, 1913, molting soldier larvæ were found in the quiescent stage in a colony of *virginicus* at Chain Bridge, Va. During the quiescent stage differentiation took place. Larvæ to all external appearances undifferentiated or of the worker type (as shown by the head, mandibles with marginal teeth, and labrum of the still adhering larval skin), the individuals (*virginicus*) being over 3 millimeters in length, in the quiescent condition, develop at this molt to pigmentless nymphs of soldiers (Pl. IX, *a*), with more elongate, soldier-like head, and mandibles without marginal teeth. In this stage the head, mandibles, labrum, and "menton" (Bugnion) have not attained the shape or length of those of the mature soldier, there being at least one later molt to maturity. After the first radical change, the head is not pigmented (the only pigmentation being at the inner margin at the tips and base of the mandibles, and at the tips of the maxillæ), not elongate, rounded, tapering toward the base (broad at apex), the mandibles shorter and broadening at base. The labrum is elongate, subelliptical, tapering at apex and slightly at base, wider than in the mature form; the "menton" is convex, tapering toward base, wider than in the mature form. The antennæ have 14 segments.

After the next molt the nymph is as yet shorter than at maturity, being from 4.5 to 5.5 millimeters in length in *flavipes*, and the head is more elongate but still broader at the apex, with the mandibles, labrum, and "menton" more elongate and slender. The antennæ have from 14 to 15 segments. At this stage the mouthparts and borders of the antennal sockets are slightly pigmented. (Pl. IX, *b*.) After another molt the full size of the mature nymph is attained and there is pigmentation of the chitinized parts (Pl. IX, *c*), there being three molts from the large-headed, worker-like larva to the mature pigmented soldier. (Pl. IX, *d*.)

It will be noted that there is a gradual elongation of the parts, as the mandibles, labrum, and "menton," and that these parts become more slender and loose in width as the mature form is reached.[a] In this connection it might be of interest to state that in the neoteinic individuals (neoteinic reproductive forms with short wing pads) the head, thoracic segments, and abdominal tergites and sternites are both longer and broader than in the reproductive forms that develop from nymphs of the first form; that is, the structure at this younger retarded early stage is more gross.

[a] Snyder, T. E. Changes during quiescent stages in the metamorphosis of termites. Proc. Ent. Soc. Wash., v. 15, no. 4, p. 162–165, pl. 6–7, Dec., 1913.

Freshly molted, immature, pigmentless nymphs of soldiers of *Termopsis angusticollis*, obtained from material collected by B. T. Harvey at Ashland, Oreg., August 28, 1913, show the same stages of development. In conclusion, therefore, it may be stated that in case of *Leucotermes* spp. and *Termopsis angusticollis* the differentiation occurs during a molt and quiescent stage rather late in the life cycle of the insect, the larvæ having belonged to all external appearances to the undifferentiated group.

SEASONAL VARIATIONS IN THE COLONY.

There are wide differences in the composition of colonies of Leucotermes at various seasons of the year.

EGGS.

In well-established colonies of *flavipes*, eggs and newly hatched or young larvæ have been found by Hubbard, in Florida, in April, May, and June; by the writer, in Virginia, in April, May, June, July, August, September, and October; in Illinois, in August; and by Odenbach, in Ohio, in September. In incipient colonies, the first eggs are laid, in Virginia, by the middle of June or July in case of *flavipes* and in July or August in the case of *virginicus*. In well-established colonies of *virginicus*, in Virginia, eggs have been found in late May and early June. In cases of artificial nests or colonies of *flavipes*, kept under observation indoors, and in cases of infested buildings, eggs have been found by Odenbach and the writer in January, February, March, April, May, July, August, September, November, and December. Odenbach's nests were from South Brooklyn, Ohio.

In case of both *flavipes* and *virginicus*, in long-established colonies the period of maximum egg production is from the middle of May to early September in Virginia; that is, during the warm months.

NYMPHS OF REPRODUCTIVE FORMS.

Nymphs of the first form of *flavipes* with easily discernible wing pads were found in the quiescent stage of the molt on August 5, 1913, at Veitch, Va. By the middle of September they had well-developed wing pads—two and one-half times the segment from which they originated—and antennæ with from 16 to 17 segments. The nymphs were from 5.5 to 6.5 millimeters in length and the compound eyes had acquired the primary reddish pigmentation. There is apparently an unaccountable annual variation, since in 1913 and 1914 nymphs were very abundant in colonies in the fall, while in 1912 they were comparatively scarce. In March, up through the time of molting, nymphs of the first form are present in the outlying channels of colonies in great numbers.

In incipient colonies nymphs are not produced during the first year that the colony is established, but are developed every year in old, well-established colonies. Nor are nymphs of the first form produced the first year in "orphaned" colonies. Nymphs of the second form are commonly to be found during the latter part of April to early May in Virginia (March in North Carolina), and they occur in varying numbers associated with nymphs of the first form. Nymphs of both forms are well developed by the middle of September of the year in which sexual maturity is attained, in *flavipes*.

Colonizing individuals of *flavipes* appear from the early part of April to May in Virginia and Maryland (earlier in infested buildings). In the case of *virginicus* they do not appear till a month later, or the end of May or early June in Virginia and Maryland. After having attained the mature pigmentation they soon swarm.

The royal individuals of *flavipes*—the pairs of winged sexed adults that have swarmed—are to be found together in the royal cell. In incipient colonies of termites, unlike the other social insects, the male assists in the establishment of the colony and continues to cohabit with the queen, there being repeated coition.

NEOTEINIC REPRODUCTIVE FORMS.

Neoteinic reproductive forms are normally(?)[a] developed from nymphs of the second form after the swarm; the males continue to cohabit with the females. Immature neoteinic reproductive forms are to be found at the time the winged sexed adults are attaining mature pigmentation—the end of April in Virginia. Maturity is probably attained shortly after the swarm, namely, May to June, although mature neoteinic reproductive forms have been found before the swarm.

In case of *virginicus*, neoteinic reproductive forms, produced from nymphs of the second form, are matured, fertilized, and egg laying by July to August. In case of *flavipes*, these reproductive forms are matured by May to June. There is a seasonal variation.

WORKERS.

Workers are always present in colonies except those just established by colonizing sexed adults; they are permanently present in the colony and constitute the most numerous caste.

---

[a] These forms can be produced at any time necessary. On April 9, 1912, a decaying stump infested with *flavipes* was removed from the forest and placed in the termitarium; this was at a time when the nymphs of the first form were nearly mature. On November 18 the termites had entered the ground and two neoteinic ergatoid(?) forms were found about 3 to 4 inches below the surface in chambers in the earth. No nymphs of the first form were present. They could be distinguished from the workers by the larger size, distended abdomen, straw-colored pigmentation, and sharper segmentation of the abdomen. Rudimentary wing pads were present. The antennæ had 15 to 16 segments. Workers solicited drops of liquid from the female by stroking the abdomen with their palpi.

SOLDIERS.

Soldiers are also always present in colonies, except those just established by colonizing sexed adults, usually a few being present in incipient colonies; they are always relatively much less numerous than the workers. From the first to the middle of August, 1913, freshly molted, pigmentless soldiers of *flavipes* were common in colonies in Virginia, where they were found as late as the middle of October. On August 17, 1913, near Chain Bridge, Va., molting larvæ and nymphs of soldiers of *virginicus* were found.

LOCATION OF THE COLONY IN WINTER.

By the middle of November to December, depending upon the season, termites retreat to the subterranean passages of the colony, the earth under infested logs being riddled by a labyrinth of galleries. In case of very large logs, termites may remain in the more impenetrable inner galleries in the heartwood. In Virginia they remain in this retreat until the last of February or first or last part of March, depending on weather conditions.

Indeed, the center of activity in termite colonies changes with the seasons, due to the varying needs of the colonies as to conditions of warmth and moisture, which are essential to life and development. In spring when there is abundant moisture, open, wooded southern exposures are favorable, and the outlying galleries of colonies are teeming with developing nymphs, whereas during the heat of summer conditions would be too dry. Consequently in summer termites bury themselves more deeply in the wood or earth in less exposed galleries, in moist, shady sites, and in winter usually enter the ground to escape the cold.[a] In autumn, developing larvæ of the castes, and nymphs of soldiers and sexed adults, are to be found in the outlying galleries where the warmth will enable more rapid development. Therefore colonies apparently depleted at certain seasons, at others will be infested. Again, the Leucotermes colony readily migrates, and the site is liable to abandonment if conditions become unfavorable. A single colony may extend to and inhabit several adjacent stumps or trees, and it is often impossible to define the limits of a colony or the line of demarcation between different colonies in a region where termite colonies are abundant and there are many decaying stumps or logs; hence what is apparently a separate colony may be only a branch connected with the main colony by subterranean passages. If colonies are cut into and the reproductive forms removed, the colony quite frequently abandons the nest. The reproductive forms are capable of movement, and it may be that old colonies branch out by means of neo-

[a] As the higher altitudes are attained, termite colonies in the earth under stones are more common; that is, in the North Carolina mountains and in cañons in Arizona.

teinic reproductive forms which eventually establish new colonies. However, this is only a theory, but otherwise what becomes of the large number of nymphs of the second form in colonies in the spring? Surely they are not needed in the parent colony any more than the winged sexed adults, and it may be that they are impelled to leave the colony by the same irresistible force that induces the swarm. However, it is probable that workers and soldiers accompany them from the parent colony and that by means of subterranean passages they establish the new nest. Indeed, these forms may be the nucleus of the small bands of foraging workers and soldiers infesting decaying branches mentioned frequently in literature. The alternative is, of course, that such bands become isolated from the parent colony and rear the reproductive forms. It seems that both methods may be possible and necessary.

DURATION OF DEVELOPMENT AND LIFE.

The eggs of *flavipes* hatch in about two weeks after they are laid. Workers developed from eggs laid on July 15, 1912, were 4.5 mm. in length by the following December, with 13 segments to the antennæ. Both workers and soldiers complete their development within one year.

Definite data on the duration of life of any individuals of Leucotermes, not excluding even the royal pair, are lacking. However, the males or true kings of *flavipes* continue to live with the true queens after copulation, the royal individuals probably living at least five years;[a] neoteinic queens live at least one year and probably as long as true queens. Smeathman conjectures that a queen of *Termes bellicosus* Smeathman when 3 inches long is about 2 years old.

CANNIBALISM.

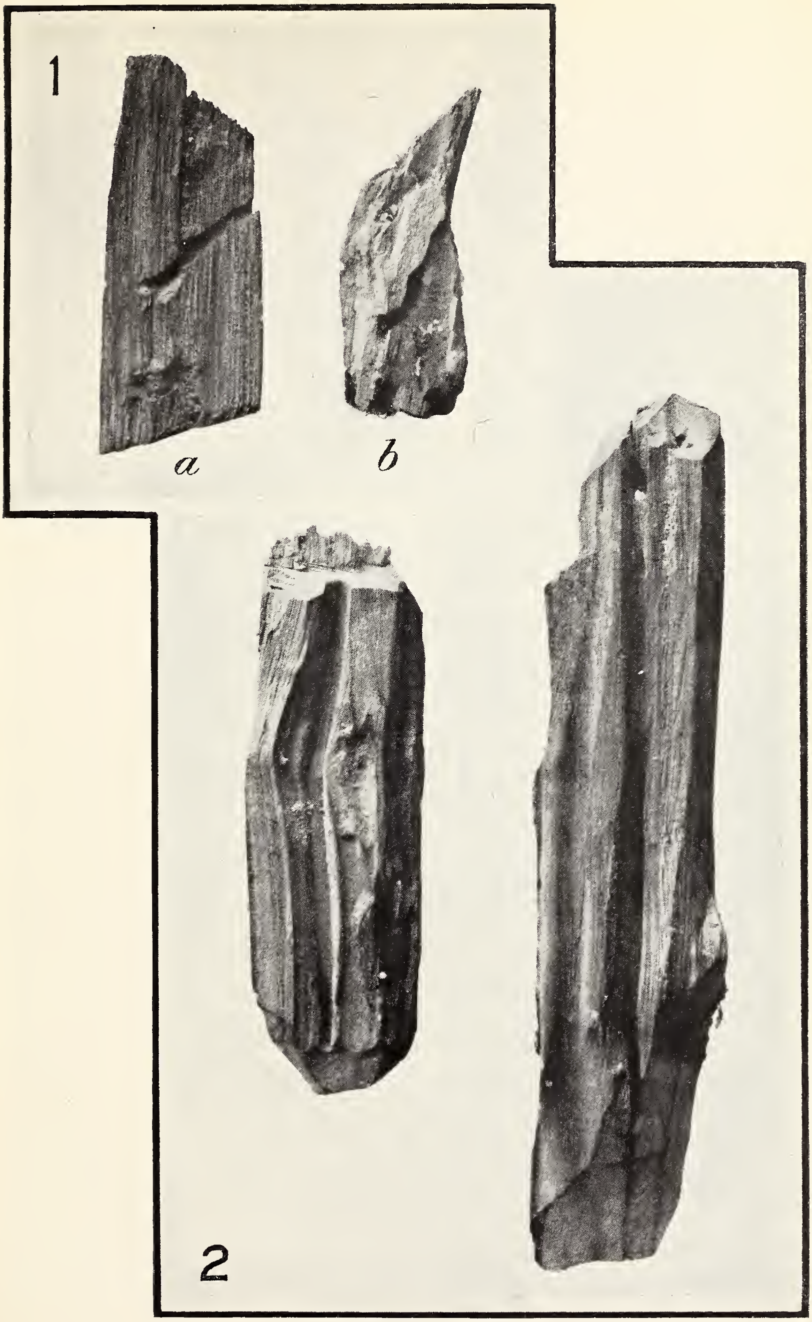
There are many instances to show that termites are cannibalistic in their habits; all dead or injured individuals are eaten; also, according to Odenbach, larvæ that have difficulty in molting.

It is not at all rare to find, especially in cases of workers, a narrow, grayish band, with black, scalloped, turned-up edges usually on the dorsum of the abdomen, but also sometimes present on the ventral surface and as a plate on the legs. This band is sometimes present on the abdomen of soldiers, and it also occurs on the thorax and head of workers. Possibly these black bands are healed-over wounds where the insects have bitten one another (fig. 9, *c*), or they may be due to a bacterial or fungous disease, or to both wound and disease.

These bands occur on workers and soldiers of both *flavipes* and *virginicus*.

---

[a] Heath, H. The longevity of members of the different castes of *Termopsis angusticollis*. Biol. Bul., v. 13, no. 3, p. 161–164, August, 1907.



LEUCOTERMES FLAVIPES.

FIG. 1.—*a*, Abandoned burrow of *Lymexylon sericeum* in solid wood of chestnut telegraph pole, in which a fertilized true queen was found; *b*, cell excavated in decaying wood by young royal couple.
FIG. 2.—Royal cell in solid chestnut in which 40 neoteinic royal individuals, for the most part queens, were found. (Original.)

On August 12, 1914, several workers with these bands on the body were taken from a colony of *flavipes* at Falls Church, Va., and placed in a small tin box with decayed wood and earth. Normal soldiers were also placed in the box. On October 2, 1914, the workers with the black bands were still alive and apparently in the same condition; the soldiers had no bands.

Chanvallon, according to Hagen,[a] recommends placing arsenic in termite nests, and since the insects are cannibals and the dead are eaten, a large number can be killed in this manner.

SITUATION OF THE DIFFERENT FORMS IN THE NEST.

The reproductive forms are not necessarily to be found in a "royal" cell situated in the more remote parts of the nests, as in tropical species, but are usually in the more sound or solid wood (Pl. XII, figs. 1, *a* and 2). In colonies recently established by colonizing individuals the eggs and young are present in a definite royal cell, where they receive the care of the queen. In well-established colonies no forms are permanently present with the reproductive forms, and there apparently is no well-defined royal cell.

The royal cell, excavated in decayed wood by the sexed adults that have swarmed, is a broad, oval chamber, the entrance to which is but slightly larger in diameter than the abdomen of the queen at a period 14 months after swarming (Pl. XII, fig. 1, *b*).

Most of the 40 neoteinic reproductive forms found at Falls Church, Va., May 27, 1912, were congregated in a single chamber in the solid wood of a chestnut slab. This chamber was a broad but shallow longitudinal cell in the solid, sound wood. The entrances to this chamber were but slightly larger in diameter than the abdomens of the fertilized queens. Other neoteinic individuals were found in shallow, broad, oval cells in the wood and in earth under the slab (Pl. XII, fig. 2).

The nymphs are usually present in the more remote passages of the nest, except during the spring, when they are in the outlying channels,[b] where the warmth of the sun will hasten their development.

---

[a] Hagen, H. A. Monographie der Termiten. Linnæa Entomologica, Bd. 10, 1855, p. 35.

[b] Developing larvæ, nymphs, or immature adults are normally to be found, temporarily at least, in that part of the nest where there are the most favorable conditions of heat and moisture for their rapid development—changing with the seasons. In the spring and autumn these forms occur under the bark on decaying stumps and under decaying wood or bark sunken in the ground in open sunny sites, always being in the outlying galleries where the warmth will enable more rapid development.

There are apparently no permanent sites used as "nurseries," as is the case in tropical species of termites. However, young larvæ are seldom found in the main unpartitioned runways, but rather in partitioned galleries, where they will not be disturbed by the activities of the other members of the colony. Often they are in broad but shallow unpartitioned galleries in the more sound wood of the interior heartwood of logs, etc.

Unpartitioned channels or runways usually contain only workers and soldiers; the partitioned channels contain larvæ and nymphs besides. The young, freshly hatched, developing larvæ are often found in broad but shallow moist galleries in the interior of the heartwood. Extensions of an old colony, consisting of subterranean passages leading to small pieces of decaying wood, contain only workers and soldiers.

As previously stated, during the winter all the castes seek the more remote or subterranean passages of the nest.

THE SWARM OR SO-CALLED NUPTIAL FLIGHT.

Under normal conditions in the Southern States,[a] in early April and May, in the case of the more common species, *flavipes*, and in June in the case of *virginicus*, the colonizing individuals emerge in enormous numbers from small holes in the wood of stumps, logs, poles, fence posts, foundation timbers in buildings, and the roots of trees and from the ground. It is 7 to 10 days after the last sexed adults have acquired wings and mature pigmentation that the swarm occurs. The winged insects usually crawl upon some elevation before taking flight; before swarming they teem over the tops of infested stumps (fig. 12) and festoon brush lying on the ground in order to get a start. If a sexed adult loses its wings while at a height above ground (as on the top of a stump) it jerks itself up in the air in endeavoring to get down. Numerous workers and soldiers are congregated in the outer layers of the wood near the exit holes at the time of emergence. These colonizing individuals differ from the other soft-bodied castes in that they are larger, of a castaneous color, and are highly specialized and developed for the purpose of swarming and starting new colonies. In addition, they are sexed and have eyes and wings. While it is true that they are weak fliers and are preyed upon by many insectivorous animals—birds, lizards, insects, etc.—yet some escape to found new colonies.

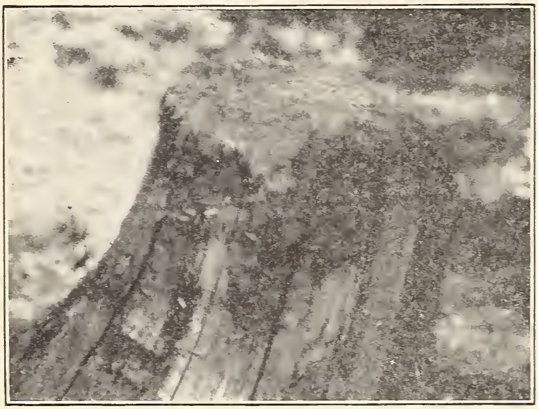


FIG. 12.—*Leucotermes flavipes:* View of a swarm of sexed adults emerging from a stump at Falls Church, Va.; a portion of the enormous numbers constituting a swarm. (Original.)

[a] The first swarm which contains the greatest number of individuals does not occur outdoors until the ripening of the pollen of the flowers of dogwood (*Cornus florida*), which is also influenced by seasonal and geographical variations.

After the adults have flown a short distance in an irregular "wobbly" manner, they fall to the ground, and by catching the tips of the wings against some object and turning sideways they pry them off at a suture or line of weakness near the base, leaving stubs. This triangular, basal portion of the wing, or stub, is thickened and more chitinized than the wing and is also pubescent up to the suture, a possible aid in breaking off the wing after flight.

The male follows the female tirelessly and persistently, with head close to her abdomen, and touches her abdomen with the antennæ. Often the male and female run in a circle of small diameter, and sometimes the pursued turns pursuer, apparently attracted by some secretion at the posterior end of the body.[a] Sometimes as many as three individuals may be seen running off together. This is apparently due to sexual attraction, an amatory procedure preliminary to pairing, which accomplishes the purpose of bringing the sexes together. This continues for several days after the flight. The sexes are attracted to each other at a period several days before swarming, as is evidenced by the fact that when a colony is broken into there is a short flight, followed by loss of the wings, after which the male follows the female in the same manner as after normal swarming.

Neither of the terms "swarm" or "nuptial flight" is appropriate in referring to the emergence of the colonizing sexed adult termites, since the insects after a short flight separate into pairs, or the males and females may even "pair" (but do not "mate" sexually till later) with individuals of other colonies, and never congregate again in the same colony, but form many new colonies. In the case of bees, on the contrary, after the swarm subsides the insects all together form one new colony. Furthermore, copulation does not take place at the time of the swarm, which is not a "nuptial flight."

THE ESTABLISHMENT OF NEW COLONIES.

Many investigators have considered that the foundation of new colonies by winged sexed adults was impossible, and was not the purpose of the swarm, but Perris (1876), Pérez (1894), and Heath (1903) disproved this.

For several days after swarming the now wingless sexed adults can commonly be found together under small pieces of decaying wood, lying on the ground, ultimately disappearing, either to excavate shallow cells in the ground, in decaying wood (Pl. XII, fig. 1, *b*), or to take possession of an old abandoned insect burrow. The entrance to this now royal cell is but slightly wider than the abdomen. It

[a] Heath, H. The habits of California termites. Biol. Bul., v. 4, no. 2, p. 47–63, figs. 3, January, 1903. See p. 54.

is here that copulation probably takes place. Doubtless many colonizing pairs, even after escaping their numerous enemies at the time of the annual swarm, fail to become established in a new colony owing to unfavorable moisture conditions. Sometimes several pairs are found together in the same cell in a piece of wood, or perhaps one male and two females, or vice versa, but these reproductive forms, unlike the neoteinic forms, are not normally polygamous. The young royal couple, after finding suitable shelter, forage for themselves and the abdomens of both sexes increase slightly in size, becoming swollen. This is probably due to feeding [a] and development of the sexual organs.[b] Heath states that "everything is apparently sacrificed to lightness of body" at the time of the swarm. This results in wider dispersal.[a] Copulation probably does not take place till about a week after the swarm, when the couples are established together in the royal cell, as sexed adults of *flavipes* that swarmed on May 8, 1912, were in royal cells on May 15, the male no longer following the female about.

While it is not essential that the colonizing pairs, the young kings and queens, be adopted by foraging workers and soldiers, it is possible that this sometimes occurs. It is significant that small branch colonies of workers and soldiers are to be commonly found under decaying pieces of wood and in the ground after the swarm.

COPULATION AND THE RATE OF EGG LAYING.

Actual copulation was not observed during these investigations, but observations indicate that copulation does not take place till after the male and queen are established in the royal cell, and copulation at the time of swarming outside the nest is not very probable, as the genitals of the males are in a very imperfect stage of development.[c] Other observers have noted the process in the case of *flavipes*.

Haviland states,[d] "In *Termes malayanus* I have reason to think that the king fertilizes the eggs after they are laid; indeed, copulation in the case of kings and fully grown queens of most species of the genus *Termes* is apparently impossible." [?]

---

[a] Heath, H. Loc. cit.

[b] Müller, Fritz. Beiträge zur kenntniss der Termiten. Jenaische Ztschr. f. méd., Bd. 7, Heft 3, p. 333–358, figs. 11, pls. 19–20, März 7, 1873. See p. 337–351.

I. Die Geschlechtstheile der Soldaten von Calotermes.

II. Die Wohnungen unserer Termiten, p. 341–358.

[c] Hagen, H. A. Some remarks upon white ants. Proc. Boston Soc. Nat. Hist., v. 20, p. 121–124, December 4, 1878.

[d] Haviland, G. D. Observations on termites, with descriptions of new species. [Read 3d June, 1897.] Jour. Linn. Soc. (London), Zool., v. 26, p. 358–442, pl. 22–25, April 1, 1898.

Grassi states:[a] "On April 17, 1891, about 11 a. m., I detected the king and queen in coitu in a glass containing a small Calotermes nest * * *. They stood end to end in a straight line with the tips of their abdomen applied to each other * * *. It is therefore certain that the connection takes place in the nest, and is repeated at intervals." Sandias states[b] that he observed what appears to be a similar process between substitute forms still far from maturity, being only about a fortnight old.

The Rev. F. L. Odenbach, of St. Ignatius College, Cleveland, Ohio, has noted (MSS.) the copulation of neoteinic royalty (*Leucotermes flavipes*), namely, the mating of supplementary queens, time and again in artificial nests. On March 11 and 29, 1898, he observed many sexed adults pairing, coitu lasting about three minutes. He further states that the same queen has connection repeatedly with different males. On December 27, 1899, in describing the pairing of neoteinic royalty with short wing pads, he states: "The introduction is a lively play with feet and feelers, heads looking in opposite ways, the bodies curved together so as to make a circle, then the male slips along the body of the female until the organs meet; then they stand in one line, heads looking in opposite directions. The body is moved backward and forward, hinging on the legs and finally to both sides, as if they wished to telescope the abdomens. Time of connection, about one minute."

Heath states[c] * * * "almost a fortnight after swarming, I have on several occasions seen the royal pair of Termopsis in coitu. With their bodies closely appressed end to end in a straight line they remain from one to ten minutes in contact."

Egg laying in the case of *flavipes* begins about the middle of June or July, varying with the season, or about one and one-half months after the swarming. While the eggs hatch in about 10 days after they are laid, larvæ of varying sizes are often present, since they do not all hatch uniformly. Most of the first broods develop workers and a few soldiers, as the workers constitute the caste most necessary to the conduct of the young colony. At this time the queen and the male still occupy the royal cell together and the queen, with abdomen only slightly distended, cares for and carries about the eggs and later the young larvæ in her mouth, when the colony is disturbed. The royal cell is kept clean and the sides are now smoothed.

Recently hatched larvæ are fed on prepared food and do not eat wood until later in their development. On January 8 and 15, 1896, Odenbach observed workers to draw a white substance of the consistency of butter from the anus of neoteinic queens and devour it.

---

[a] Grassi, B., and Sandias, A. Op cit., p. 285–286.
[b] Ibid., p. 386.
[c] Heath, Harold. Op. cit., p. 52.

On November 18, 1912, workers were observed to solicit liquid from the anus of a larval or ergatoid (?) queen, at Falls Church, Va. On August 5, 1913, a fertilized, fully developed queen, collected at Veitch, Va., about 14 millimeters in length, ejected a clear white liquid from the anus, when disturbed.

The rate of egg laying of the young and active queen is not very rapid, as clusters of eggs in varying numbers from about 6 to 12 were observed in several cells with single pairs. The new colony at first is very small, and even after the rearing of the first brood of workers and soldiers the increase in numbers is not rapid. In July, 1912, at Falls Church, Va., about 12 small white eggs in a cluster were observed in a royal cell with young royal individuals of *flavipes*. At least three were observed, probably 2 males and 1 female. These had been captured after the swarm on May 8, in the earth under a small piece of decaying wood. On July 29 the newly hatched larvæ were observed, and on October 30 seven workers and one soldier surrounded a single royal pair. Fragments of the chitinized parts of another adult were found near the royal cell. The abdomen of an egg-laying female under observation, 13 months after swarming, was oblong and somewhat distended, the segments of the abdomen being slightly separated and showing white between. On October 30, when the female in the royal cell was disturbed, she continually moved the end of the abdomen, curving it ventrally under the body. This alternate rising and falling of the abdomen has been described by Smeathman as a constant "peristaltic" movement, in the case of tropical species. No eggs had been laid since the first were deposited in July, and it is believed that this so-called "peristaltic" movement in case of Leucotermes is merely the result of alarm, and has no direct bearing on egg laying. During this time the male still occupied the cell with the female and both were active. Eventually the abdomen of the female becomes immensely distended through the development of the ovaries, but in the case of certain species of Leucotermes the queen still retains the power of locomotion.

It will thus be seen that development under the foregoing conditions is at best a slow process and not at all comparable to that which takes place in tropical species, where growth of the queen and the rate of egg laying is correspondingly rapid.

On February 21, 1913, nine or more additional eggs were observed in a cluster near the royal cell of the above-mentioned pair. This cell was in a small decayed branch, placed on moist earth, and isolated in a tin box. On February 24 the first freshly hatched larva was observed. The abdomen of the queen at this time was not markedly distended. On May 16 freshly hatched larvæ were again present in this colony. On August 15 six eggs, as well as newly hatched young, were present in the royal cell. The male still cohabited with the

queen, and the abdomen of the queen was not as yet markedly distended.

While the recently hatched young are active, they are dependent on the care of the parents or upon the workers for food.

Wheeler[a] states, "In incipient ant colonies, the queen mother takes no food, often for as long a period as eight or nine months, and during all this time is compelled to feed her first brood of larvæ exclusively on the excretions of her salivary glands. This diet, which is purely qualitative, though very limited in quantity, produces only workers and these of an extremely small size (micrergates)." In incipient termite colonies (Leucotermes and Termopsis[b]) the young royal couple share the royal cell, excavated in decaying wood, at which time the abdomens of both the sexed adults increase slightly in size, and they take food—that is, wood. The first larvæ develop to workers and a few soldiers, both forms being smaller than normal individuals or those in well-established colonies. No nymphs of sexed adults are produced during the first year. The rate of egg laying of a fully developed true queen is much more rapid. On August 5, 1913, at 5 p. m., a true queen, about 14 millimeters long, which had been taken in the root of a dead chestnut tree above ground, was isolated with the king in a cell in wood. By 9 a. m. on August 6, more than 12 eggs had been laid. When captured in the tree there were several hundred eggs as well as numerous recently hatched larvæ near by.

The antennæ of some true royal pairs that have swarmed are apparently entire at a period of seven months after swarming; however, the segments were not actually counted. In other pairs the antennæ of both sexes are mutilated.

THE ROYAL PAIR AND OTHER REPRODUCTIVE FORMS.

OCCURRENCE IN THE UNITED STATES.

Feytaud[c] gives a historical account of the frequency of occurrence of reproductive forms of *L. lucifugus* in Europe and figures the reproductive forms. Between April and September in the eastern United States the several types of reproductive forms of our common species of termites are to be found in colonies in decaying wood above ground; that is, the pigmented, true royal pair with wing stubs, developed from the sexually mature adults; the supplementary neoteinic forms, with pale straw-colored pigmentation and short wing pads, developed from nymphs of the second form; and the ergatoids and neoteinic larval forms, with straw-colored pigmentation and no wing pads or rudiments, developed from mouldable larvæ. It is believed that since these forms are mobile and that in

[a] Op. cit., p. 68. [b] Heath, H. Op. cit., p. 57. [c] Loc. cit.

old, well-established colonies there is apparently no definite permanent royal cell, these forms inhabit the subterranean passages in wood or in the earth below the frost line during the winter. During the warm months, probably to facilitate the processes of reproduction and development of the young, they inhabit the passages in decaying wood above ground. The occurrence of true royal pairs is not rare,[a] but supplementary or neoteinic reproductive forms are apparently more common in colonies.

HISTORICAL.

The following is a historical record, in chronological sequence, of the occurrence of reproductive forms in colonies of *Leucotermes flavipes* and *L. virginicus* in the United States, together with notes on the conditions under which they were found.

The first queens of *flavipes* taken [b] in the United States were found by the late H. G. Hubbard in a colony in Florida and were of the neoteinic type, or supplementary form, with short wing pads. Hubbard also found the first neoteinic kings, although he makes no mention of them and may not have recognized the fact that he had found both sexes of neoteinic reproductive forms. Some of the neoteinic queens that Hubbard collected are deposited in the Hagen collection at Cambridge, Mass., but most of the specimens are in the collection of the United States National Museum. The number of specimens now present in the vials at the museum is probably not as great as when originally collected, since Hubbard gave certain of the royal individuals to Hagen. Hubbard's note, dated "Enterprise, Fla., May 19, 1875," recording the finding of the first reproductive forms in the United States, reads: "*Termes flavipes* (determined by Hagen), females with their eggs from small, rotten log in road near lake shore; females not in separate cells, several together." [This vial also contained two supplementary kings and nymphs of the first form.] Another note dated April 4, 1882, Crescent City, Fla., reads: "*Termes flavipes*, nymphs, queens, and eggs from galleries in pine log; Trichopsenius and Anacyptus were found in this nest." [A neoteinic king was also present in the vial.] A note dated "May 11, 1883, Crescent City, Fla., in pitch pine," is in a vial containing 11 neoteinic queens, 5 neoteinic kings, and 631 eggs with the embryos in various stages of development. [Nymphs of the first form were also present in this vial.]

---

[a] It was formerly thought that true queens did not exist in colonies in the United States and Europe (proper). According to E. A. Schwarz (Termitidæ observed in southwestern Texas in 1895. Proc. Ent. Soc. Wash., v. 4, no. 1, p. 38–42, Nov. 5, 1896), there are but few permanent nests, headed by true royalty, of Leucotermes, due to the wandering habit of the genus; that is, the frequent moving of colonies would necessitate such rarity.

[b] Hagen, H. A. The probable danger from white ants. Amer. Nat., v. 10, p. 401–410, July, 1876. See p. 405.

Mr. Louis H. Joutel,[a] of New York City, found a number of fertilized, egg-laying neoteinic queens occupying the same cell, 9 in one colony and 14 in another. The number varies with the colony, as has since been ascertained, and many neoteinic royal individuals may be present in a small colony, where they would be more needful. Mr. Joutel spent several years in the study of termites, and in correspondence with the writer states that on two separate occasions he has found true queens—the first shortly after the finding, in 1893, of the above-mentioned neoteinic queens. This would be the earliest record of the finding of a true queen of *flavipes* in this country. He further states that on a later occasion he found two true queens at Peekskill, N. Y., on the same day, July 14, under about the same conditions. The queens were located in a "* * * dead hickory stump, about 12 inches diameter, and were in the upper part of the tunnels among the workers. There was nothing to suggest a queen cell and no eggs to be found, although I looked over them carefully. They were found in stumps about 20 to 30 feet apart." In commenting on a statement made by the writer[b] that a true queen was inactive in a burrow when discovered, Mr. Joutel states: "The three [true queens] that I found were very active, and while they did not move quite as fast as the larvæ [workers], it was due only to their size." Mr. Joutel is quite right, as I have since found out, and the instance cited was probably due to the queen being caught in a burrow too narrow for her distended abdomen, in trying to escape, rather than being confined in a cell the entrance to which was narrower than the size of her abdomen. While Mr. Joutel was the first actually to find a true queen, Mr. C. Schaeffer,[a] of Brooklyn, N. Y., was the first to record the finding of a fertilized, true queen of *flavipes*, at Moshulu, N. Y., July 16, 1902. He has kindly loaned the specimen to me for study. This queen is approximately 8 millimeters in length, the abdominal tergites and sternites not being widely separated, is markedly pubescent, and the antennæ are mutilated.

In describing the true queens which he found, Mr. Joutel states that they resembled the queen that Mr. Schaeffer found. He further states, "* * * they were all apparently broader than the one you figure in relation to its length. The heavy chitinized parts looked like little dots on the surface and did not take up as much space in relation to the rest of the surface as those parts do in the one you figure. [True, in living specimens.] The first one had its antennæ complete; of the other two, one had two segments missing on one antenna and the other had three segments wanting—

[a] Loc. cit.

[b] Snyder, T. E. Record of the finding of a true queen of *Termes flavipes* Kol. Proc. Ent. Soc., Wash., v. 14, no. 2, p. 107–108, June 19, 1912.

these happened to be on the same side." He also says, "I have repeatedly taken a pair at swarming time and bred the eggs from them, but have never got them to colony size," and that "* * * in stating that I found only three queens, I had reference to the fully developed ones. On Staten Island, in company with Mr. W. T. Davis, I came across a small log that had eight separate cells with a king and queen in each. A few had three and one four (individuals). They had eggs but no young. Some had perfect antennæ and others had segments missing." He states: "One small colony that I kept alive several years that had only about two or three dozen workers *swarmed* each year, a few individuals only, but I broke up and examined each fragment of wood and sifted the ground several times but never found a trace of either kind of queen; the whole colony was contained in a gallon jar. Other colonies that had thousands of workers, which I kept alive about 22 months from time of collecting, never swarmed or had young, but finally died of old age, I presume. They got smaller and seemed to have more fat in their makeup." Mr. Joutel also says, "Light, I found, was not objected to by termites, unless it was too strong, as long as they felt that they were *covered*, that is, they worked under cover, not necessarily in the dark." This is true, but even in metal termitariums with sliding, thick, red glass covers, termites, while at first they actively wandered about on the surface of the earth, and were apparently unaffected, soon sought cover under decaying pieces of wood or in the earth.

The Rev. F. L. Odenbach, S. J., has, since 1895, made observations on the habits of *Leucotermes flavipes* in artificial colonies. He has roughly sketched in his notes two types of neoteinic queens that he has found. The neoteinic kings he describes as being compressed laterally, and therefore seeming to have a ridged back. One neoteinic queen, with short wing pads, that he found pairing was 10 millimeters in length and had a markedly distended abdomen. Another gravid queen that he figures is apparently adapted from a nymph of the first form, since long, well-developed wing pads are present. The abdomen is distended and the abdominal tergites are separated. He states:

These reproductive forms were from a very large nest I took up in South Brooklyn, near Cleveland, Ohio, in the fall of 1895.

I placed the termites in a large glass globe. In September, 1897, I discovered a large mass of eggs from which were developed all the different nymph forms known to me, *true winged males and females* also in large numbers. These latter chased about the nest in such wild disorder for a few days that the workers fell upon them and destroyed them to the very last one. It reminded me of the slaughter of drones in a beehive. At the time it seemed to me that the wild orgies, [?] which as a rule occur outside of the nest in midair, disconcerted the workers and soldiers who did the next best thing to restore order and quiet in their household.

From the above large nest I caused a colony to migrate into a Lubbock nest, and in this nest I found the different neoteinic reproductive forms. First, the nymph

with the long wing pads. She laid eggs, and I repeatedly induced her to do so by the same means by which I first caused ant workers to lay eggs (1885).

If they seem numb with cold, I place my hand on the glass plate and this induces the activity.

This queen was quite different in shape and color from those I will mention below, being larger and of a lighter color. She was slow in her movements and did not change her location very often. She was tended by the workers, which could hardly be said of the others, since they were too restless.

The others, reproductive individuals, were nymphs of different kinds, with different shaped wing pads, but none with as long ones as those of the individual mentioned above. They also laid eggs, but during one of their wild rushes around the nest were given their quietus. I now had only the above nymph and the one with no visible wing pads left. This latter I thought to be a true queen (?), since the treatment of her was nothing like that accorded to the nymph with long wing pads. She laid eggs, but seemed to be disregarded by the workers.

On March 26, 1895, at Haw Creek, Fla., Hubbard found an imago (a male) with the wings gone, in a colony. The antennæ have segments missing. His note reads, "In old, rotten pine log in swamp hummock; soldiers, larvæ, and imago with wings gone."

King [a] also states that he has found a black form (male) with wing stumps in a colony and that it is a swift runner. "Again, there is associated with *Termes flavipes* a clear black form, variable in size, some with wing stumps, and others, so far as I can see now, without being cleared, appear to have none. [?] I have only met with five of these forms so far; one measured 6 mm. in length, another 5 mm., and two of these measure 4 mm." He states that the fifth form was sent, not long since, to Dr. L. O. Howard, with notes, who referred it to Mr. E. A. Schwarz, the latter stating that it was a fully developed male with wing stumps.

Mr. King further says:

"* * * When I first observed its appearance with *Termes flavipes*, and in the nest with it, I supposed it to be a species of a staphylinid beetle, so swift were its movements that they made them quite deceptive. They are very swift runners and hard to capture. Further observations will be necessary to determine whether these are new species or not. It is my impression, however, that they are of a different type."

He does not state at what period of the year he found this form.

These forms found by Hubbard and King were possibly royal individuals, and in the case of the specimens collected by Mr. King they were possibly of both species, *flavipes* and *virginicus*.

H. G. Hubbard found a true queen of Leucotermes, probably *lucifugus* (a species very similar to *flavipes* [b]). As in *virginicus* the ocelli are nearer to the compound eyes than in *flavipes*. *L. virginicus*

[a] King, G. B. *Termes flavipes* Kollar and its association with ants. Ent. News, v. 8, No. 8, p. 193–196, October, 1897. See p. 194.

[b] Hagen, H. A. Monographie der Termiten. Linnæa Entomologica, v. 12, 1858, p. 174–180 and 182–185.

Banks has as yet been found only in Virginia, West Virginia (Hopkins), Maryland, North Carolina, and Illinois (Snyder). *Leucotermes lucifugus* Rossi occurs in the United States and "is found in Texas, Kansas, Colorado, and southern California, and perhaps elsewhere."[a] The species *lucifugus* of Mediterranean Europe, according to E. A. Schwarz,[b] is probably native to America (Mexico). According to Dr. Knower, *flavipes* has been introduced into Japan and is firmly established. This species has also been introduced into Europe and has been destructive in the vicinity of Vienna.

This true queen, found by Hubbard, is slightly over 13 millimeters in length, has the abdominal tergites and sternites more projecting, and has not as greatly distended an abdomen as the true queen found in Virginia; that is, the chitinized parts are less fused than in the older queen. (Pl. XIII, *b*.)

The note in Hubbard's field diary recording the discovery of the first fertilized true queen reads as follows:

June 20th, 1898, Santa Rita Mountains, Madera Cañon (Southern Arizona). We ascended a ravine filled with majestic sycamore trees under which the ground was wet with numerous springs, but entirely tramped by cattle and devoid of smaller vegetation. * * * I found under a stone in a little dry mound in a wet springy spot on the mountain side, a colony of true Termes, among which, in a cell cavity just beneath the stone was a single matured gravid female, or queen, which certainly had been winged; took eggs, larvæ, workers, and soldiers with the queen. This is the first instance known of a true queen in the genus Termes. There were no supplementary or nymphal queens in this colony and no male was found. I explored the entire colony, which was not a large one.

Prof. Harold Heath, of Stanford University, Cal., has described the life cycle of *Leucotermes lucifugus* in California,[c] which is very similar to that of our common species of the East. He figures a true "primary" queen, as only 8 months old, however, that has a markedly distended abdomen and the abdominal tergites separated—probably an error, due to transposed descriptions under the figures, according to observations by Feytaud [d] and the writer.

A true queen, with wing stubs (*flavipes*), found by the writer was in an abandoned burrow of *Lymexylon sericeum* Harr. (Pl. XIII, *b*) in the decaying butt of a chestnut telegraph pole near Portsmouth, Va., on August 12, 1910. This queen was inactive, since the burrow was no wider than her abdomen, and apparently she was unattended. The abdomen was greatly distended and oblong in shape, the abdominal tergites and sternites being widely separated. In the bright sunlight the abdomen appeared to have a yellowish green tinge. The length of the queen was approximately 14 millimeters. The antennæ were mutilated.

---

[a] Howard, L. O. The Insect Book. p. 356. New York, 1901.

[b] Loc. cit. See p. 39.

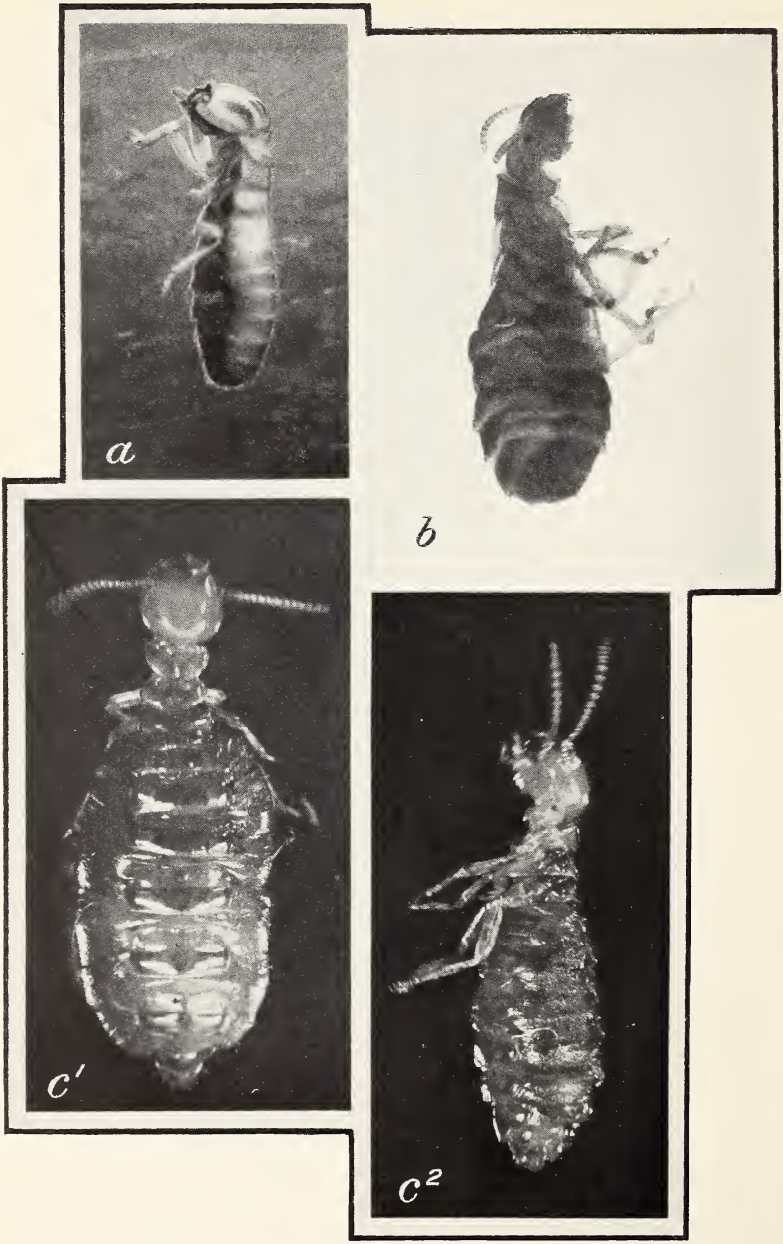
[c] Heath, Harold. Loc. cit.

[d] Feytaud, J. Op. cit., p. 567, fig. 21.

FIG. 1.—*a*, Supplementary queen with straw-colored pigmentation to chitinized parts; *b*, true queen with castaneous pigmentation to chitinized parts. (Original.)

FIG. 2.—Supplementary and true queen, showing deeper pigmentation of chitinized parts of the true queen. (Original.)

LEUCOTERMES FLAVIPES.



LEUCOTERMES VIRGINICUS AND L. FLAVIPES.

a, *L. virginicus*, neoteinic larval reproductive form; *b*, *L. flavipes*, neoteinic nymphal reproductive form (queen); c^1, c^2, *L. flavipes*, neoteinic larval queens, dorsal and ventral views (note absence of wing pads). From etherized specimens. Enlarged 10 times. (Original.)

Mr. W. B. Parker, of the Bureau of Entomology, has found two large fertilized true queens of *Leucotermes lucifugus* in redwood hop-poles in California. These queens were found in May, one being approximately 8 millimeters in length, with 11 segments to the antennæ, the other approximately 6 millimeters in length, with antennæ broken. Like the queen found by Mr. Schaeffer, the abdomens were not fully distended.

At Falls Church, Va., during the seasons of 1912, 1913, and 1914, numerous nymphs of the second form, in stages before, during, and after molting, were found by the writer; also young and mature neoteinic reproductive forms and young and mature true royal individuals.

On April 23, 1912, at Falls Church, the first colony of *flavipes* was found with a nymph of the second form present. The abdomen was noticeably broader, and this nymph was active and associated with nymphs of the first form. The nymphs of the first form were fully developed and in various stages to the sexed adults with immature pigmentation. Freshly hatched young larvæ were present. The day was sunny and warm.

On the same day a colony of *flavipes* was found in a decaying tulip tree stump, established well in the heartwood. Sexed adults with mature castaneous-black pigmentation were present and flew when the colony was disturbed. They were not present in large numbers, and all were in the outer layers of the wood. No fully developed nymphs in the stage just before the final molt were present, which is remarkable, as they were apparently present in all other near-by colonies. Very young nymphs and half-grown nymphs, as well as larvæ just hatched and young to medium-sized larvæ, workers, soldiers, and two neoteinic males (mature kings?) were present. They were active and in the outer layers of the wood. The abdomens of these males tapered markedly, being narrower at the end of the abdomen. They had a yellowish brown pigmentation, and in one king the compound eyes were without a trace of pigmentation. (Pl. VIII, fig. 2, *a*.)

A small colony of *flavipes* was found on April 25, 1912, under a small chestnut slab lying on the ground, exposed but sunken compactly into the moist earth. The day was sunny and warm. Fully developed nymphs of the first form were the most abundant stage, although some few transforming nymphs and a few sexed adults with dark pigmentation, as well as a few soldiers and workers, were present. The next most abundant caste to nymphs of the first form was nymphs of the second form, of which 90 were present and 4 were molting. They were active, much more so than nymphs of the first form. Most of these forms were either in shallow tunnels in the earth or on the earth, but a few were found in the decaying wood.

On the same day a single nymph of the second form was taken in a small colony under a strip of chestnut bark compactly pressed into the ground; this nymph was associated with nymphs of the first form. In two other colonies single nymphs of the second form were found associated with sexed adults under the bark on decaying chestnut stumps. Normally, but relatively few nymphs of the second form, as compared to nymphs of the first form, are present in colonies.

In another colony about one dozen nymphs of the second form, one of which was molting, were found associated with adults with pigmentation in various stages of development to maturity. A few of the latter with mature pigmentation had only one pair of wings unfolded, whereas others were present with the wings at the tips still compactly folded.

In a near-by colony, nymphs of the second form that had completed the final molt were present with sexed adults, but unlike the foregoing they are darker, some being pigmented. Very young larvæ were present in the outer layers of the wood. The acquisition of pigmentation in neoteinic royalty apparently is a sign of maturity and old age.

On May 27, 1912, 40 neoteinic forms, for the most part fertilized queens, together with females in which the abdomen was not greatly distended, were found in the more solid wood of a decaying chestnut slab on the ground. (Pl. XII, fig. 2.) Smaller forms, males, with the abdomen not oblong or distended were present in the colony. Most of these forms were congregated in the longitudinal royal chamber, in which young were also present. According to Grassi,[a] in case of *lucifugus*, "The colony must therefore rear fresh (complementary) kings every year [?], which become mature in August and September, fertilize the queens, and die." In colonies in Virginia neoteinic reproductive forms of *flavipes* are being developed from nymphs of the second form during April and May and are matured by May to June. In case of *virginicus* these reproductive forms are matured by July to August. There is a seasonal variation. There is no conclusive evidence that the kings do not live as long as the queens. They are not always present with the queens in colonies, but being so much more active are more likely to elude capture.

Two sexed adults, a royal couple, were captured by C. T. Greene at Falls Church, on November 12, in the frass in an old burrow of *Prionoxystus robiniæ* Peck, in the base of a living chestnut tree. Three royal individuals were present in the frass, and were located from 2 to 3 inches deep in the burrow. Four to six (at most) young were present, and, according to Mr. Greene, apparently all were workers.

[a] Grassi, B., and Sandias, A., op. cit., p. 298.

On November 18, 1912, two larval (ergatoid?) reproductive forms with a yellowish pigmentation and rudimentary wing pads were found in passages in the ground under a decayed stump at Falls Church.

Nymphs of the second form greatly outnumbered nymphs of the first form in a colony of *flavipes* taken in a decaying oak limb on the ground on March 22, 1913, at Black Mountain, N. C.

On April 17, 1913, at Falls Church, molting nymphs of the second form of *flavipes* were found together with molting nymphs of the first form, some of the former of which had already molted and attained the characteristic yellowish pigmentation.

Molting nymphs of the first and second forms of *virginicus* were found on April 30, 1913, at Falls Church, under decaying slabs of wood on the ground.

Mr. H. S. Barber, of the Bureau of Entomology, on May 30, 1913, on the Virginia shore of the Potomac River, opposite Plummers Island, Md., found a neoteinic reproductive form of *flavipes*. This was a queen exceeding 6 millimeters in length, with wing buds and 17 segments to the antennæ. This queen was associated with workers, soldiers, and young in decaying pine wood on the ground. (Pl. XIV, *b*.)

On May 26, 1913, nine neoteinic queens of *flavipes* with distended abdomens and one king were found near Charteroak, Pa., in the interior of a decaying maple stump. Freshly hatched young and young larvæ were numerous. The queens were not in separate cells, but were active and associated with workers and soldiers. (Pl. XV.)

Mr. H. G. Barber, under the title "Another Queen of the White Ant Found," states:[a]

> While on a collecting excursion last Fourth of July with Mr. Charles E. Sleight, at Lake Hopatcong, N. J., I found a small colony of white ants beneath a small log where they had made some tunnels along the ground beneath the log. Among the individuals was captured a fully developed queen, which was preserved and presented to the local collection of insects, at the American Museum of Natural History.

A large fertilized true queen and a king of *flavipes* were found on August 5, at Veitch, Va., in a large colony associated with workers, soldiers, and young and several hundred unhatched eggs in the sound outer layers of wood, about 1 inch in from the exterior, near the base of a dead standing chestnut tree. This tree had died at least two years previous, but this may not approximate the age of the colony, since termites often infest the bases of living trees by obtaining entrance through old abandoned insect burrows. The king was hidden beneath the queen, which was about 14 millimeters in length. The antennæ of the queen in this instance were mutilated

[a] Barber, H. G. Another queen of the white ant found. Jour. N. Y. Ent. Soc., v. 22, no. 1, p. 73, March, 1914.

and the workers and soldiers were very solicitous. It is evident that the queen is fed on food prepared by the workers, since her abdomen became markedly shrunken when she was isolated.

On August 7, 1913, another true royal couple of this species was found near Chain Bridge, Va., in the interior of a decayed yellow poplar (tulip tree) log lying on the ground. The colony was small and the abdomen of the queen was not fully distended, being more flat than oblong. (Pl. XVI, *b*, king.)

On August 15, 1913, at Falls Church, a young neoteinic reproductive form? (female) of *virginicus* was found in an experimental stake of decaying yellow pine which had been set in the ground a year previous. The queen (?) was of a dirty yellow color with four grayish-black longitudinal markings on the epicranium, and grayish-black markings between the coxæ and mesothoracic and metathoracic tergites. The length was 4.5 millimeters. The segments to the antennæ were mutilated, one antenna having 11 segments. (Pl. XIV, *a*.) There was no pigmentation to the compound eyes.

On September 17, 1913, near Chain Bridge, Va., numerous nymphs of the second form of *flavipes* of mature size were found associated with nymphs of the first form in the sound heartwood of a decaying black locust stump. The nymphs of the first form had well-developed wing pads.

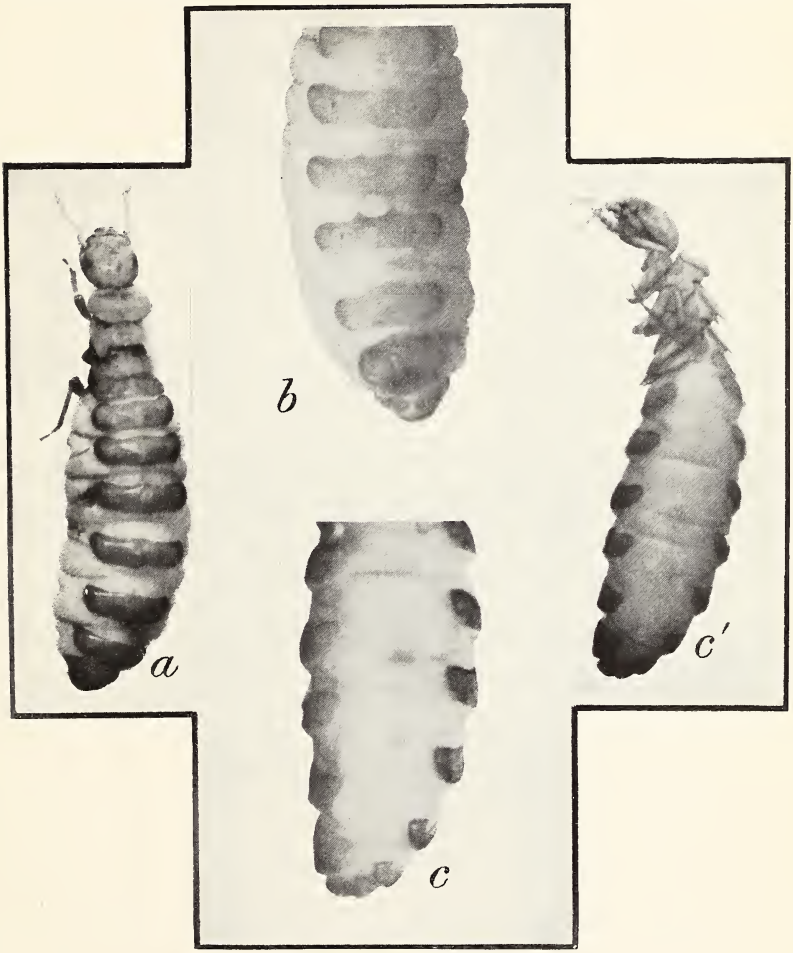
On November 3, 1913, at Falls Church, nymphs of the second form of *flavipes* were found associated with those of the first form in the sound wood of a decayed oak stump near the ground. Young were present in this colony.

In 1914, on April 17, the first fully developed nymphs of the second form of *Leucotermes flavipes* were found in colonies at Falls Church, Va.

A large true queen of *flavipes* was found in a decayed oak stump about 5 feet high on July 17, 1914, at Falls Church. The tree had been dead for at least three to four years, and the stump was about 14 inches in diameter and still had the bark on. This queen, which was oblong but somewhat quadrate—4 millimeters in width—was 14½ millimeters in length (measured while alive [a]), and in color had a slight tinge of greenish-yellow or opaqueness. The antennæ had segments missing. The colony was very large. Numerous eggs were present in the galleries in the decayed wood, and the queen was found in an elliptical cell about 2 inches in the wood from the exterior; the sides of the cell were cleanly eaten out. The royal cell was situated about 1½ feet above the surface of the ground. The male was not found.

---

[a] The abdomens of queens become further elongated during the killing and fixing process, and hence in photographs of preserved specimens there is an apparent loss in width.



LEUCOTERMES FLAVIPES.

a, Dorsal, *b*, ventral, and *c*, *c'*, lateral views of abdomen of fertilized nymphal neoteinic queens. *a* and *c'*, Enlarged 7 times; *b* and *c*, enlarged 10 times. (Original.)

LEUCOTERMES FLAVIPES.

a, Mature king, nine months after the swarm and cohabitation with a true queen that had reared a brood of young—abdomen of queen not markedly distended; *b*, mature king, probably several years old, cohabiting with fertilized queen with abdomen markedly distended and tergites and sternites separated; *c*, fertilized true queen that swarmed April 25, 1913, and by September 25, 1913, was rearing a brood of young; *d*, Same, dorsal view. *a*, Enlarged 7 times; *b*, *c*, *d*, enlarged 10 times. (Original.)

In a near-by dead oak tree about 1 foot in diameter, which had been dead probably for two years, another true queen of this species was found on the same day. This queen was oblong and approximately $12\frac{1}{2}$ millimeters in length (measured while living). The royal cell was in the decayed wood about one-half inch from the exterior at the base of the tree near the roots. The colony was large in numbers. Hundreds of eggs in clusters were in shallow galleries under the bark. The male was not found. Sometimes eggs in large clusters were found in deep, transverse, conical ledges or notches, attended by workers.

When the royal cell is cut into and the queen removed, the large number of attending soldiers and workers become very much excited, as evidenced by constant convulsive movements or sudden jerking of the whole body.

In this same woodland, on July 20, four neoteinic queens of *flavipes* were found in the more solid wood of a low (the wood above ground being nearly disintegrated) decayed oak stump, near the surface of the ground. One queen was of the normal neoteinic type, developed from a nymph of the second form, being 9 millimeters in length, with wing pads present. The compound eyes were pigmented, and the antennæ consisted of 16 segments. The other three neoteinic queens were of a type not previously found in colonies by the writer. These queens, of a straw-colored pigmentation, were 7, 6, and 5 millimeters in length (measured while alive), respectively. In shape the abdomens are oblong quadrate, like those of the true queens. The antennæ comprise 15 segments, which have a tinge of grayish-brown pigmentation to the dorsal surface. No wing-pads or rudimentary buds are present. The compound eyes are without pigmentation. The head, thoracic segments, and tergal and sternal "nota" (chitinized tergal and sternal areas) are not as broad as in neoteinic reproductive forms developed from nymphs of the second form. In these larval queens, as in true queens, the segments of the abdomen are less projecting than in normal neoteinic queens, and the "nota" are less semicircular. The mouth parts and legs are also less gross in structure. Indeed, these queens more nearly approach the true queens as to these points. (Pl. XIV, *c*.) They were probably developed from larvæ of the sexed forms. The outline of rows of numerous eggs in various stages of development could be seen through the body tissue under a high-power Zeiss binocular. The body tissue of normal neoteinic queens is coarser and thicker. This is the first time that reproductive forms of apparently different types have been found in the same colony of this species. The colony of termites in which these queens were found was small in numbers.

All the queens found by the writer in July, 1914, at Falls Church were captured within an area of ground less than an acre in extent.

It is believed that the spread or distribution of a colony may be largely dependent on the supply of decaying wood near by; that is, if there is a large amount near by (as colonies in large dead trees) the colony will not branch out over a large area.

On August 5, 1914, at Falls Church, a true royal pair of *flavipes* was found in a cell in the more solid wood of a decaying oak chopping block, that is, a section of a log that had been put to this use in the woods. The cell was in a knotty area of solid wood about 1½ feet from the ground but in the outer layers. The king was hiding beneath the queen, and is 6 millimeters in length. The abdomen is distended and the antennæ mutilated. The queen was of large size (probably 10 to 12 millimeters in length) but was crushed in cutting into the royal cell. The colony was large, and galleries extended from the ground up through this block and another similar block placed on top of it. The termites had filled in the crevices between the two blocks with clay, and larvæ, pupæ, and adults of *Homovalgus squamiger* Beauvois, a scarabæid beetle, were present in the termite galleries in the clay or in pupal cells.

In the same woods several young royal pairs of *flavipes* were found established in incipient colonies in the outer layers of a decaying chestnut slab partially sunken in the ground. Each pair was in a shallow cell excavated in the wood and was surrounded by a few young larvæ (a half dozen to a dozen). A few unhatched eggs were present in some of the cells. In one of the cells three adults were present instead of simply one pair. This is quite often the case in incipient colonies.

At Veitch, Va., on August 12, eight neoteinic reproductive forms of *flavipes* were found in a decaying yellow pine stump. They were in the more solid wood about 1 foot from the ground, but in the outer layers. Five were females and three were males or kings. The females were all about 7 millimeters in length, with abdomens distended with eggs, but with the segments not markedly separated except near the end of the abdomen, where the latter was lumpy and distorted, due to distension. The males, with narrow, slender abdomens, were all about 6½ millimeters in length, but had, instead of the straw-colored pigmentation of the females, a darker pigmentation streaked with grayish-black markings on the head and borders of the tergites and sternites and between the coxæ and the mesothoracic and metathoracic tergites. The antennæ of these reproductive forms consisted of 16 to 17 segments. These forms were developed from nymphs of the second form. The colony was not very large, but numerous unhatched eggs and young larvæ were present.

At Lake Toxaway, N. C., on August 27, 1914, an ergatoid queen of *Leucotermes virginicus* was found under a large flat rock in a shallow cell in the earth. Workers, soldiers, and young were aggregated

under the stone, but the colony was not large. This queen had no trace of wing pads or pigmentation to the compound eyes, if present. The abdomen is oblong-ovate, being distended; its length is 5 millimeters. The antennæ are mutilated. Workers and soldiers surrounding the queen ran up and touched her with the antennæ and then evidenced excitement and alarm by the convulsive jerking of the body backward and forward.

This locality is a wooded, rocky hillside at an elevation of about 3,400 feet above sea level. There had been surface fires through the forest. It was noted that termite colonies were unusually abundant in the earth under stones in this locality, which is apparently the case as the higher elevations are reached.

On September 15, 1914, near Chain Bridge, Va., well-developed nymphs of both the first and second forms of *flavipes* were found in a colony in the more solid wood of a decaying chestnut stump. There is an annual seasonal variation in the degree of development the nymphs of the first form have attained by late fall; sometimes the wing pads are long and the nymphs apparently nearly mature; in other years in March these nymphs will still have comparatively short wing pads. There is sometimes also a variation in the different colonies.

DESCRIPTION OF THE REPRODUCTIVE FORMS.

As has been previously stated, the abdomens of both the young queen and male increase slightly in size and become distended after swarming. The abdomen of queens (*flavipes*) that had laid eggs during July, in January (9 months after swarming) were oblong and somewhat distended, the segments of the abdomen being slightly separated and showing white tissue between. The queens are dark castaneous in color and the males more blackish. The legs, tarsi, and tibiæ are markedly light yellowish in color in both sexes. After the swarming the abdomens of the males become only slightly distended.

The gradual distension of the abdomen of the queen, brought about by ovarian development, necessitates the separation of the abdominal tergites and sternites, and the connecting tissue between the abdominal tergites, pleurites, and sternites becomes remarkably distended, or more probably, according to Hagen,[a] as stated by Riley, there is actually further growth after the insect has reached the imaginal stage. It may be noticed from the illustration of the true queen found by the writer on August 12, 1911 (Pl. XIII, *b*), that there are two brownish scars located on the pleural tissue on the right side of the abdomen. These were not noticed until the queen was

[a] Riley, C. V. Termites, or white ants. Proc. Biol. Soc. Wash., v. 9, pp. 31–36, Apr., 1894.

removed from the cell, and were probably due to injury received in shipment, as the queen was not taken from the royal cell, but a small block of wood was cut out of the pole, the whole having been placed in a vial of alcohol. The queen was partly out of the cell and the scars were probably due to abrasions by small fragments of jagged, projecting wood. This is stated in detail, because it might be thought that the wounds were "battle scars."

Attached to the mesothorax and metathorax in true queens are the stubs of wings, lost at the time of swarming. The head, thorax, and scutellar area ("nota") of the abdominal segments of true queens are more heavily chitinized and more deeply pigmented with castaneous brown than in the neoteinic queens, developed from nymphs of the second form, which are straw-colored (Pl. XIII, *a*); consequently, the nonfunctional eyes and ocelli are not so prominent in neoteinic queens, which never develop wings and which always[a] (?) remain in the parent colony. The head, thoracic tergites, and abdominal tergites and sternites are both longer and broader than in the true queens, which same differences are apparent in the nymphs. (Pl. VIII.) In true queens the mesothoracic and metathoracic tergites have a distinctively irregular shape. The chitinized "nota" of the abdominal tergites and sternites more markedly approach the semicircular in shape and are much more projecting in neoteinic queens developed from nymphs of the second form. However, in younger (smaller) true queens (*flavipes* and *lucifugus*) the tergites and sternites are slightly more projecting than in older queens. Furthermore, the legs are more slender and the mouth parts slightly smaller (less gross) in true queens. The mesothorax and metathorax and pigmented, chitinized "nota" have a distinctive shape in the neoteinic larval queens. (Pl. XIV, *c*.)

In matured true queens (of both *flavipes* and *lucifugus*) ribbons of parallel ovules of various sizes and stages of development are visible (under high-power Zeiss binocular) through the tissue of the abdomen, where there are no deposits of fat. Sections through the body show an enormous ovary development, with ribbons of ovules in progressive stages of development. In a lateral or dorsal view of the abdomen of the true queen, small, round spiracles can be seen, set in at the base of the lateral slope of the tergites. (Fig. 13, *a* and *c*.) The spiracles are approximately similarly placed on queens of species in the genera Calotermes Hagen, Termopsis Heer, and Eutermes Fr. Müller. In some tropical species, as in *Termes bellicosus*, the spiracles are located in the pleural tissue of queens with enormously

[a] It may be possible that subcolonies or offshoots of large old colonies are established by these mobile queens and workers and soldiers by means of subterranean passages to decaying wood.

distended abdomens, an indication of displacement by actual post-adult growth (?). In tropical species of Eutermes the enormous development of the ovaries in old queens crowds the digestive and excretory organs to the ventral surface of the abdomen.

Situated on the vertex of the epicranium is a small depression which appears as a rather prominent white spot, under the binocular microscope, in workers, nymphs, and neoteinic royal individuals of *flavipes*. This depression, slightly larger in diameter than an ocellus, is also present in the soldiers and in colonizing individuals. This is the "retrocerebral gland"[a] mentioned by Grassi,[b] as a "* * * [gland of unknown function," [existing in *lucifugus*] "(only?) in the nymph of the first form, the perfect insect, and the soldier. It eliminates a transparent secretion which can be squirted out for some distance."]

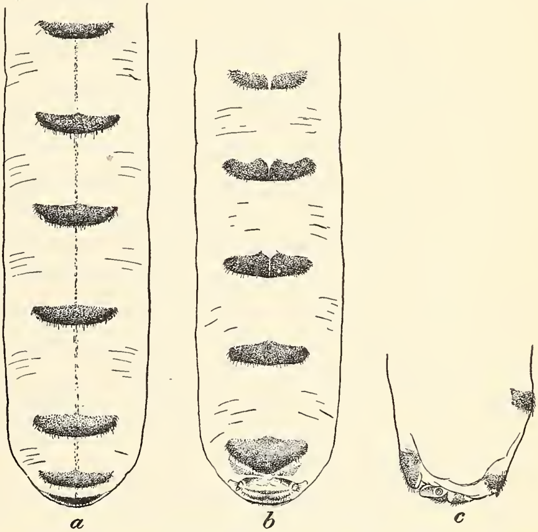


FIG. 13.—*Leucotermes flavipes:* Fertilized, true queen; dorsal (*a*), ventral (*b*), and lateral (*c*) views of abdomen. Drawn from specimen preserved for three years in alcohol. Note position of spiracles. (Original.)

While the abdomens of neoteinic queens apparently never become as elongate as in true queens, they become as much distended, but have not the oblong or quadrate shape, being more oval, or wider near the end of the abdomen, which tapers markedly. At the end of the abdomen of true queens the chitinized parts are more compressed or fused than in the neoteinic forms.

Fertilized, neoteinic queens, developed from nymphs of the second form, range in length from 9 to 12 millimeters. The males are of the same length as the nymphs from which they develop; their abdomens are compressed laterally and taper toward the end, and "therefore seem to have a more narrow ridged back" (Odenbach).

Neoteinic or supplementary royal individuals are obtained from an arrested early stage in the development of the nymphs of the first

[a] Homologous to the small head gland of worker-like larvæ of Eutermes, which larvæ develop to nasuti, with a nose-like process (?).

[b] Grassi, B., and Sandias, A. Op. cit., p. 317.

form, or even larvæ, as young are kept in an undifferentiated state, which can be speedily turned into reproductive forms that serve as substitutes. Fritz Müller[a] compares the modes of diffusion and reproduction to those of plants which continue the species by means of cleistogamic as well as perfect flowers, the neoteinic forms corresponding to the cleistogamic flowers which are supplementary, emergency forms for use in case the perfect flowers (or winged colonizing forms) should fail. The winged forms would furnish a possible, but not probable, escape from interbreeding, since, usually, males and females from the same colony pair. Neoteinic supplementary forms are produced not only to counterbalance the loss of true royalty but also for the purpose of extending the colony.

DATES OF THE SWARMING OF LEUCOTERMES.

Colonizing individuals of *Leucotermes flavipes* usually swarm in the forenoon during the first part of April and May in the southern part of the eastern United States. Farther north the swarm occurs later, usually the last of May or early June. Hagen [b] mentions an exceptionally large swarm which occurred in Massachusetts. The sexed adults normally emerge earlier in infested buildings. According to E. A. Schwarz, sexed adults swarmed from infested beams in the floor in the basement of the old United States National Museum on March 15, 1883, the second year after the opening of the museum. The following year they swarmed during the latter part of March.

On April 16, 1910, sexed adults, possibly from the same colony, swarmed from crevices between the bricks in the sidewalk opposite the old National Museum.

On March 30, 1908, sexed adults came up through cracks in the floor in a building at Philadelphia, Pa.

Mr. Schwarz states, in an article entitled "Termitidæ Observed in Southwestern Texas in 1895": [c]

> *Termes flavipes* Kol.—Common throughout southwestern Texas and very destructive to woodwork in houses. An immense swarm of winged individuals [*lucifugus?*] issued from several houses at San Diego [Tex.], on October 25. I was informed that in early spring another flight takes place in buildings infested by termites [*flavipes?*]. What appears to be the same species is also common in sticks and branches lying on the ground in the chaparral, but I failed to get the winged form from such situations.

---

[a] Müller, Fritz. Beitrage zur Kenntniss der Termiten. III. Die Nymphen mit kurzen Flügelscheiden (Hagen), "nymphes de la deuxième forme" (Lespès). Ein Sultan in seinem Harem. Jenaische Ztschr., Bd. 7, Heft 4, p. 451–463, figs. 3, November 18, 1873.

[b] Hagen, H. Some remarks upon white ants, Proc. Boston Soc. Nat. Hist., vol. 20, p. 121–124, December 4, 1878.

[c] Proc. Ent. Soc. Wash., vol. 4, no. 1, p. 38–42, November 5, 1896. See p. 38.

W. D. Hunter states [a]:

> *Termes flavipes* K. is not uncommon in Texas, where swarms occur ordinarily during the early part of the season. In 1911, however, the insect did not come into notice until about the middle of October [*lucifugus?*]. At that time much more than usual numbers were to be seen throughout the State.

Often several swarms emerge from the same colony in the same year. At McDonogh, Md., in April, 1913, according to a correspondent, sexed adults swarmed from the woodwork of a house, the beams being honeycombed. A very large swarm issued on April 6, another on April 13, a third on April 18, and a fourth swarm issued April 25, comprising in all four distinct swarms. In size, however, the first swarm, from my observations, is usually the largest. (Fig. 12.)

Leucotermes virginicus swarms during the forenoon in the vicinity of Washington, D. C., usually one month later than *flavipes*, or in early June. However, on August 11, 1913, at Falls Church, Mr. William Middleton observed a large swarm to emerge from a small chestnut corner stake which was set in the ground. The colony, which was not large, swarmed at 12.30 p. m.

Leucotermes lucifugus, according to Heath,[b] swarms "* * * at different times between the months of October and April * * *." "It usually takes place about 11 a. m."

During the early part of May, 1909, sexed adults of *Leucotermes* sp. (probably *flavipes*) were observed by the writer emerging in great numbers from the ground in the fenced yard of an old house located in a pine grove near Woodville, Tyler County, Tex. The swarm occurred in the forenoon of a warm, sunny day.

The following notes were made by members of the branch of Southern Field Crop Insect Investigations, in charge of Mr. W. D. Hunter:

> On September 12, 1910, a light shower fell, and before the rain had entirely stopped the air was full of flying termites; this lasted one hour. On December 16, 1910, there was a swarm [*lucifugus*] at Dallas, Tex. After a rain at Dallas, October 13, 1911, there was a swarm; another rain brought them out on October 16, 1911. On October 18, 1912, there were swarms of termites at Dallas, following a two-day's rain.

It will be seen from the foregoing that reliance, in the determination of species, can be placed on the dates of swarming, since the species *flavipes* never swarms in the fall in the eastern United States. Apparently rainfall has no influence on the time of swarming, as is the case in Texas.

---

[a] Hunter, W. D. Some notes on insect abundance in Texas in 1911. Proc. Ent. Soc. Wash., vol. 14, no. 2, p. 62–66, June 19, 1912. See p. 63.

[b] Op. cit., p. 52.

ASSOCIATION WITH ANTS.

Grassi [a] and Escherich [b] have given interesting accounts of the relations between termites and ants. S. A. Forbes [c] states that *flavipes* has been found associated with *Formica schaufussi* Mayr. H. C. McCook [d] states that *flavipes* occurring under stones in the neighborhood of the Alleghenies were seized and carried off by the mound building ants (*Formica exsectoides* Forel) when disturbed. J. C. Branner [e] refers to the common ants as being enemies of the termites. King [f] has noted the association of termites with ants. The following brief notes have been made while investigating damage by termites to trees and forest products:

Termites and ants are commonly to be found inhabiting the same log or stump, yet ants are the enemies most to be feared by termites, as they will capture and carry away the members of a disorganized colony. Ordinarily the relations between termites and ants seem to be neighborly and peaceful. If the termite colony is opened up and disorganized, the ants at once take advantage of the opportunity and carry away the termites, which offer but little resistance. Ants of several species may be attracted to such a helpless colony from a distance. The soft-bodied soldiers are apparently not very effective in such emergencies, although in the narrow channels of the colony, where the powerful head with open mandibles is the only front presented to the marauding ants, they afford some protection to the colony.

Two species of carpenter ants (*Camponotus pennsylvanicus* Mayr and *Cremastogaster lineolata* Say [g]) are the ants which more commonly have been found associated with termites in the eastern United States. The latter species, due to its small size and rapidity of movement, is a most formidable enemy.

Ants greatly diminish the number of the colonizing individuals at the time of the swarm, carrying them away as they are running about on the ground. Soldiers and workers guard the breaches from which the sexed adults have emerged, possibly to keep the greedy ants from following their prey to the parent nest.

---

[a] Grassi, B., and Sandias, A. Op. cit., p. 282–283.

[b] Escherich, K. Die Termiten oder weissen Ameisen. Eine biologische Studie, p. 122–126, Leipzig, 1909.

[c] Forbes, S. A. Nineteenth Report of the State Entomologist on the Noxious and Beneficial Insects of the State of Illinois, p. 198, Springfield, Ill., 1895. The white ant in Illinois (*Termes flavipes*, Kollar), p. 190–204.

[d] McCook, H. C. Note on mound-making ants. Proc. Acad. Nat. Sci. Phila. for 1879, p. 154–156, August 12, 1879.

[e] Branner, J. C. Geologic work of ants in tropical America. Bul. Geol. Soc. Amer., v. 21, p. 449–496, figs. 11, pl. 35, August 20, 1910. See p. 478–479.

[f] Loc. cit.

[g] Identified by Mr. Theodore Pergande, of the Bureau of Entomology.

TERMITOPHILOUS INSECTS.

The presence of termitophilous insects or "guests" in colonies of *Leucotermes flavipes* in the United States has been recorded by several writers on termites. Mr. E. A. Schwarz[a] has published an extensive list of Coleoptera associated with *flavipes*. Inquilines, or guests, are found only in permanent colonies and, as brought out by Mr. Schwarz,[b] might be of importance in establishing the original habitat of a species; that is, if a termite species had peculiar inquilines (guests that do not occur among other species of termites) in one country and none in another, it would indicate that the termite species was native to the country where the inquilines occur in its colonies. Mr. H. G. Hubbard found the staphylinid beetles *Trichopsenius* and *Anacyptus* in a colony with supplementary royalty, April 20, 1882, near Crescent City, Fla. He also found peculiar wingless psocids which resemble young termites in a colony of the latter, near Haw Creek, Fla., March 26, 1895. The note in his field diary reads:

> Termitophilous psocid found with termites in large log of pine, swampy hummock of Prairie Farm. Several specimens in alcohol, together with worker of termite. * * * The resemblance to a young termite is perfect, especially in mature specimens. * * * The psocid is, however, much more active than the termite and very difficult to capture. Immature specimens were not rare. * * * The immature specimens inhabit the galleries of the termites, but are not so apt to be found among the termites as in their immediate vicinity.

King[c] records three inquilinous staphylinid beetles as associated with *flavipes*, *Philotermes pilosus* Kraätz, *Homalota* sp., and *Tachyporus jocosus* Say.

All stages of small scarabæids, *Homovalgus squamiger* Beauvois and *Valgus canaliculatus* Fabricius, are commonly found associated with termites in decaying wood in Maryland, Virginia, West Virginia, and North Carolina, and are probably truly inquilinous. From the middle of July, 1914, prepupal larvæ and pupæ of *Homovalgus squamiger* were commonly found in decaying wood infested by termites and in the galleries of termites in Virginia. Adults of this beetle begin to mature about the middle of August. The larvæ construct oval pupal cells in the decayed wood or make them of earth; the interior is smooth and glossy. This beetle is probably a true inquiline.

---

[a] Schwarz, E. A. Termitophilous Coleoptera found in North America. Proc. Ent. Soc. Wash., vol. 1, no. 3, p. 160–161, March 30, 1889.

Schwarz. E. A. Additions to the lists of North American termitophilous and myrmecophilous Coleoptera. Proc. Ent. Soc. Wash., vol. 3, no. 2, p. 73–78, January 8, 1895.

[b] Schwarz, E. A. Termitidæ observed in southwestern Texas in 1895. Proc. Ent. Soc. Wash., vol. 4, no. 1, p. 38–42, November 5, 1896.

[c] Op. cit., p. 196.

Beetles of the family Pselaphidæ are frequently found in decaying wood near termite nests, and some are known to be their guests. Adults of *Tmesiphorus carinatus* Say [a] were found in decaying wood in which colonies of *flavipes* were present at Falls Church on March 18, 1912. Mr. E. A. Schwarz has included this species in his list of myrmecophilous beetles as "often found among ants of various species." [b] Adults of *Batrisus virginiæ* Casey [a] were found in decaying wood infested with *virginicus* on the same day.

Adults of the staphylinid, *Philotermes pennsylvanicus* Kraätz [a] were collected with *flavipes* near Kane, Ill., August 11, 1911, in the butt of a decaying white cedar telegraph pole. The species is a true inquiline, and the beetles are very active. On August 16, 1913, near Chain Bridge, Va., an adult of *Philotermes* sp. (possibly *fuchsii* Kraätz) (determined by Mr. H. S. Barber of the Bureau of Entomology) was found in a colony of *virginicus*. Blatchley [c] records *Philotermes pilosus* Kraätz and *P. fuchsii* Kraätz in the nests of *flavipes* in Indiana.

PARASITES.

Termites are infested externally with mites and internally with protozoan parasites, but no internal or external feeding insect parasites have been recorded by Leidy,[d] Grassi,[e] or Porter.[f] Grassi states that the presence of these protozoa in the intestine retards sexual development, as evidenced in the case of workers and soldiers. He further states that they are normally absent in the reproductive forms and newly hatched larvæ.

SUMMARY AND CONCLUSIONS BASED ON THE RESULTS OF THE EXPERIMENTS.

The following conclusions are based on observations of colonies in the termitarium, colonies in small tin boxes, and other colonies in the forest at Falls Church.

Colonizing individuals of both sexes swarm together from colonies of *Leucotermes flavipes* and *L. virginicus* from about 11 a. m. to 1 p. m., the length of time occupied by the adults in emerging being about one hour. No evidence of the separate swarming of the sexes

---

[a] Identified by Mr. E. A. Schwarz.

[b] Schwarz, E. A. Myrmecophilous Coleoptera, found in temperate North America, Proc. Ent. Soc. Wash., v. 1, No. 4, p. 237–247, May 15, 1890.

[c] Blatchley, W. S. The Coleoptera or beetles of Indiana, p. 343–344, Indianapolis, 1910.

[d] Leidy, J. On intestinal parasites of *Termes flavipes*. Proc. Acad. Nat. Sci. Phila. [v. 29] for 1877, p. 146–149, June 26, 1877.

Leidy, J. The parasites of the termites. Jour. Acad. Nat. Sci. Phila., ser. 2, v. 8, p. 425–447, pls. 51–52, February, 1881.

[e] Grassi, B., and Sandias, A. Op. cit., p. 11–13.

[f] Porter, J. F. Trichonympha and other parasites of *Termes flavipes*. Bul. Mus. Comp. Zool., v. 31, no. 3, p. 45–68, pls. 6, October, 1897.

or seasonal dimorphism has been observed. However, all the individuals do not necessarily emerge from the same colony at the same time, since there may be several swarms from the same nest. On May 14, 1912, at Falls Church sexed adults of *flavipes* emerged, although not in great numbers, from colonies, whereas there was evidence, by the discarded wings on the ground, of an earlier swarm. Most of the colonizing individuals had swarmed from other colonies on May 8; yet some individuals, not in the enormous numbers of the first swarm, were observed swarming from the same colonies on May 14. While there may be as many as four swarms, the first is usually the largest. This may be explained by the fact that there is an uneven development of individuals. Indeed, a few retarded, winged, sexed adults (*virginicus*) may remain in the colony till July 24 (near Kane, Ill.) and early August (District of Columbia) or be found, as individuals, flying. A large swarm of *virginicus* has emerged from a colony as late as August 11, 1913, at Falls Church.

The winged insects usually crawl up to some elevated place before taking flight. There is an enormous mortality of the colonizing individuals, and insectivorous animals destroy them in great numbers. The swarm is not a "nuptial flight."

The so-called "amatory passages" possess a sexual significance, and there is a mutual attraction between the sexes several days before the normal period of swarming. This can be observed if the colony is disturbed and the colonizing forms emerge prematurely, and is evidenced even before the loss of the wings. This attraction, probably due to some secretion, continues till after the royal pair is established in the royal cell and copulation has taken place. Copulation probably occurs a week after the swarm of *flavipes;* that is, on May 15 adults that had swarmed on May 8 were in the royal cell and apparently no longer following each other about, head close to abdomen, as previously. There is evidence that individuals of neither sex are sexually mature at the time of swarming, and that there is further development before copulation, as can be noted in the increase in size of the abdomen of both sexes.

The colonizing individuals are not all irretrievably lost.[a] The establishment of new colonies by these forms is a normal process. Although there is an enormous mortality at the time of the swarm, and a still further diminution in numbers due to inability to become established under favorable conditions, yet some pairs do become established. These sexed adults are not necessarily monogamous.

---

[a] Perris, E. Nouvelles promenades entomologiques, *Termes lucifugus.* Ann. Soc. Ent. France, sér. 5, t. 6, p. 201–202, 1876.

Pérez, J. Sur la formation de colonies nouvelles chez le termite lucifuge (*Termes lucifugus*). Compt. Rend. Acad. Sci. (Paris), t. 119, No. 19, p. 804–806, Nov. 5, 1894.

Heath, Harold. Loc. cit.

True royal pairs are independent of workers in the foundation of new colonies; that is, it is not necessary that they be found and established in royal cells by foraging workers and soldiers, although it is possible that this occurs, which would then constitute an independent colony. New colonies established by sexed adults that swarmed were found both in the termitarium (where conditions were similar to those in nature) and in the forest. The king and queen are equally important; they continue to cohabit and coition is repeated. The first brood reared by young true queens that have swarmed consists of workers and soldiers of smaller size than the normal form.

Neoteinic royal individuals are to be found commonly in colonies of *flavipes* in the eastern United States; they are "ergatoids" or "neotenes" and are developed by retarding the normal development of nymphs of the first form at an early stage, and from young larvæ; sometimes as many as 40 or more, consisting of many queens and a few males, may be present in the same colony. The males are polygamous. It is believed that these forms are provided (1) when overcrowded old colonies are split up and new, independent colonies are to be established, or (2) through the actual loss of the true royalty or by the accidental separation of some members of the colony from the royalty. This method of the formation of new colonies is sure, and probably much more rapid in the case of establishment by the true colonizing forms, as the royalty would receive the care of the workers, would not have to forage for themselves, and their only function would be reproduction. The number of eggs laid and the rate of increase would necessarily be much more rapid, due to the following facts: (1) The abdomens of mature, fertilized, supplementary queens are nearly as fully distended as in the case of true queens; (2) the large number of supplementary royalty possible to be present in a single colony and consequent increase in the number of eggs laid, and (3) the proper care and nourishment the royalty would receive.

It is often noted that the antennæ of the reproductive forms are mutilated, that is, have a greater or less number of segments missing. However, this is not always the case in young reproductive forms. The loss of the segments in individuals in long-established colonies might be due to the treatment the latter receive from the workers, or from being dragged about by them, but the antennæ are sometimes mutilated in individuals in incipient colonies.

There is a series of molts and "quiescent stages" in the development of the larvæ of the castes; caste differentiation occurs during such a stage, which corresponds somewhat to the pupal stage in insects with complete metamorphoses.

In conclusion, the more important facts may be summarized as follows: There is great variation in the life cycle of Leucotermes;

FIG. 1.—Chestnut telephone pole, with base charred but basal area untreated. This pole has been standing near Dover, N. J., for eight years. (Photograph loaned by United States Forest Service.)

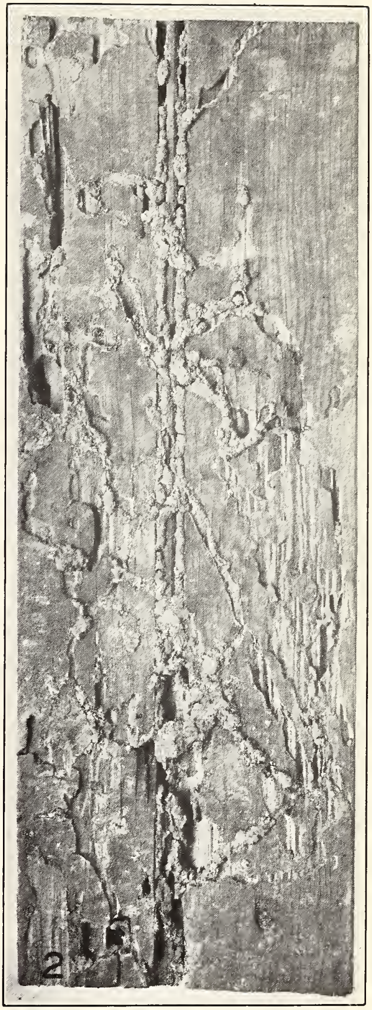


FIG. 2.—Pine flooring honeycombed by termites at New Iberia, La. (Original.)

DAMAGE BY TERMITES.

these insects are adapted to meet emergencies successfully and overcome obstacles without the disorganization of the colony. New colonies may be established (1) by the sexed colonizing adults that invariably swarm and leave the parent colony; (2) by neoteinic royal individuals, produced from nymphs of the second form which never (?) leave the parent colony, or from young larvæ, as in colonies orphaned after the nymphs of the first form have nearly completed their development; (3) by neoteinic reproductive forms supplied to orphaned colonies, which may be derived from nymphs of the first or second forms, or larvæ. Nests headed by true royalty are not rare, but many difficulties are to be surmounted in their establishment by sexed adults; such recently established colonies are small in number. Nests headed by neoteinic reproductive forms are more commonly to be found, as this is a more sure and more rapid method of establishment. Colonies established by neoteinic reproductive forms necessarily increase in size more rapidly due to the numerous egg-laying queens and the care and food they receive from the workers. Subcolonies or temporary colonies are frequently found with only workers and soldiers present; these subcolonies, which furnish increased facilities for habitation and food supplies, are possibly offshoots from the parent colony or nest and are established by means of subterranean passages, which are extended for long distances by foraging workers and soldiers.

THE DAMAGE TO FOREST PRODUCTS.

Termites seriously injure construction timbers in bridges,[a] wharves, and like structures; telephone and telegraph poles[b] (Pl. XVII, fig. 1), hop poles,[c] mine props,[d] fence posts and rails or boarding; lumber piled on the ground, railroad ties set in the ground (not where there is stone or slag ballast or heavy traffic), woodwork (Pl. V; Pl. XVII, fig. 2) in new and old buildings,[e] and especially seriously damage the wooden boxing or "conduits" of insulated cables placed in the ground (to the detriment of the insulation); tent pins and ridge poles, wooden

[a] Hagen, H. A. The probable danger from white ants. Amer. Nat., v. 10, no. 7, p. 401–410, July, 1876.

[b] Snyder, T. E. Insects injurious to forests and forest products. Damage to chestnut telephone and telegraph poles by wood-boring insects. U. S. Dept. Agr., Bur. Ent., Bul. 94, pt. 1, pp. 12, figs. 3, pls. 2, December 31, 1910. See p. 9–10.

[c] Parker, W. B. California redwood attacked by *Termes lucifugus* Rossi. Jour. Econ. Ent., v. 4, no. 5, p. 422–423, October, 1911.

[d] Snyder, T. E. Insect damage to mine props and methods of preventing the injury. U. S. Dept. Agr., Bur. Ent., Circ. 156, pp. 4, July 13, 1912. See p. 2–3.

[e] Marlatt, C. L. The white ant. (*Termes flavipes* Koll.). U. S. Dept. Agr., Bur. Ent., Circ. 50, rev. ed., pp. 8, figs. 4, January 27, 1908.

Hopkins, A. D. Insect injuries to forest products. U. S. Dept. Agr. Yearbook 1904, p. 381–398, 1905. White ants, or termites, p. 389–390.

beehives and tree boxes; wooden electrotype blocks, and books (Pl. IV) and documents stored in damp, dark places, etc.; timber in contact with the ground being especially liable to serious damage. Often the damaged material has to be removed and replaced, or rebuilt. The wood of no species of native tree of commercial importance is "immune" to attack, although some are relatively more resistant than others. Such damage has occurred as far north as Boston and the shores of the Great Lakes, but greatly increases as the Tropics are approached. In the Southern States termites are especially destructive to wooden underpinning, beams, and flooring (Pl. XVII, fig. 2), and all other material of wood accessible in buildings. They enter buildings by means of tunnels through the ground, by way of wooden joists, or by means of covered paths (minute "sheds" constructed of earth and excrement of the superficial consistency of sand), leading to the woodwork over the surface foundations of stone or other material which they can not penetrate. This enables them to avoid the light. Thus termites silently, secretly, and ceaselessly work their insidious damage, instinctively never perforating the exposed surface of timber, except to enable the sexed adults to swarm. Sometimes the emergence of these winged forms is the first indication of their presence, but at other times joists and floors collapse without warning.

PREVENTIVES, REMEDIES, AND "IMMUNE" WOODS.

Forest products in contact with the ground should be impregnated with coal-tar creosote, which is a permanent preventive against attack by our native termites. Coal-tar creosote has many properties which would recommend its use in this respect, for it is also a fungicide, and, being insoluble in water, will not leach out in wet locations. These requirements furnish objections to many chemicals that otherwise are very effective insecticides. The various methods of superficially treating timber, as by charring, by brushing, or by dipping with various chemical preservatives, among which are creosotes, carbolineums, etc., have proven to be temporarily effective in preventing attack,[a] if the work is thoroughly done. If not thoroughly done, termites enter through the untreated or imperfectly treated portions, especially through weathering checks and knots. Where the bases of poles, mine props, etc., are left untreated termites enter the timber from below, and, avoiding the treated portions, come up through the interior. Charred timber is effective against termite attack for a period less than a year, although it is not seriously damaged at the end of one year. It will readily be seen that neither brushing nor spraying the exterior after place-

[a] Snyder, T. E. Insects injurious to forests and forest products. Damage to chestnut telephone and telegraph poles by wood-boring insects. U. S. Dept. Agr., Bur. Ent., Bul. 94, pt. 1. pp. 12, figs. 3, pls. 2, Dec. 31, 1910. See p. 9–10.

ment, as is sometimes practiced, is effective in keeping out termites, since the portion that sets in the ground could not be treated, and it is usually at this point that termite attack occurs.

Before treating timber with chemical preservatives, especially where the brush method is employed, it is essential that the timber be thoroughly seasoned, otherwise penetration by the preservative will be retarded.

A treatment with "blue oil" is recorded as apparently effective in protecting wood against the attacks of "white ants," or termites, besides acting as a preservative (fungicide) generally. "Blue oil"[a] is the residue left in the distillation of mineral oils after the isolation of kerosene (petroleum) and paraffin; (*a*) the oil to be a shale product; (*b*) its specific gravity (at 60° F.) to be 0.873 to 0.883; (*c*) its flashing temperature to be not lower than 275° F. (close test).

Many patented wood preservatives, advertised as effective against wood borers, often merely contain simple preservatives, as for instance, linseed oil, to which a slight odor of oil of citronella has been imparted, or contain simple poisons. For timber to be set in the ground, brush coatings with linseed oil are not effective against termites.

An English firm manufactures a saccharine solution which probably contains a salt as arsenic[b]; this patented treatment is supposed to be efficient against wood-boring insects, especially termites. The wood is seasoned by immersing in the saccharine solution at 120 to 140° F. This process is being tested.

Impregnation with chlorinated naphthalene may prove effective against termites, as a preservative for woodwork, in interior finish, where a requirement is that the preservative should not "sweat" out, or stain the wood. Treated wood blocks buried in the ground with termite-infested logs were not attacked after a test of nearly six months.[c] Impregnation with paraffin wax was not effective (fig. 14). If the wood is not in contact with the ground, impregnation treatments with bichlorid of mercury and zinc chlorid are effective. The mercury and zinc in this form are both soluble in water.

H. W. Bates, in a paper entitled "On the prevention of destruction of timbers by termites," Transactions of the Entomological Society of London, 1864, Vol. I, p. 185, cites preventive measures. M. J. Berkeley, in The Technologist, (London), 1865, Vol. V, p. 453, gives remedies based on the report by the committee of inquiry into

---

[a] The protection of timber against white ants. Trans. Roy. Scot. Arbor. Soc., v. 23, pt. 2, p. 227–228, July, 1910.

Dixon, W. B. Protection from "white ants" and other pests. Nature, v. 85, no. 2148, p. 271, December 29, 1910.

[b] Chemical abstracts, v. 7, no. 2, p. 408, January 20, 1913.

[c] Impregnation of wood to resist insect attack. Amer. Lumberman, no. 2009, p. 32, November 15, 1913.

the ravages by white ants at St. Helena. Froggatt gives[a] preventive measures applicable in New South Wales.

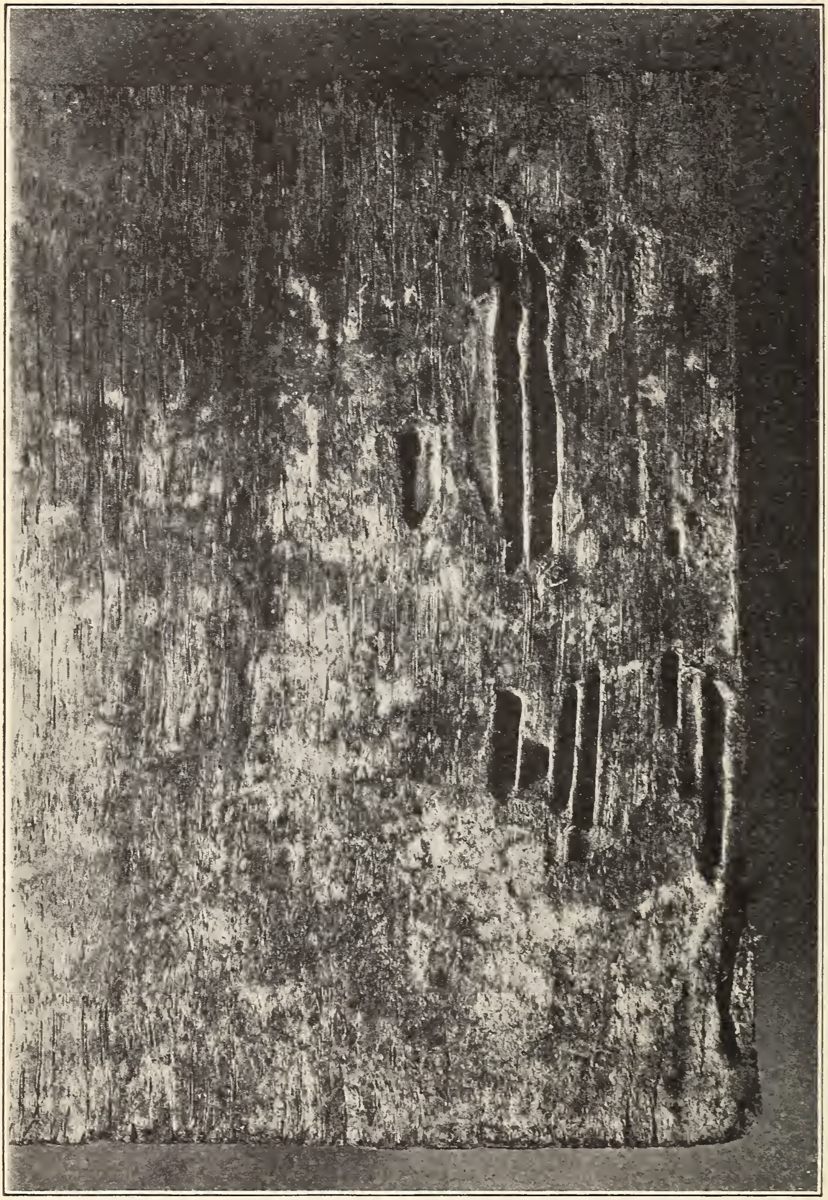


FIG. 14.—Red oak block, impregnated with paraffin wax, honeycombed by termites after five months' test. This was buried in the ground with termite-infested logs. (Original.)

[a] Froggatt, W. W. White ants, with some account of their habits and depredations. Misc. Pub. no. 155, Dept. Agr., Sydney, N. S. Wales, Sydney, 1897. See p. 6–8, account of depredations and methods of prevention.

The wood-pulp products and various patented "composition boards" used as substitutes for lath, etc., might be made termite proof by adding during their manufacture such poisons as white arsenic, antimony, bichlorid of mercury, zinc chlorid, etc; tests are being conducted.

In general, serious damage by termites to the wood of fire or insect killed, standing, merchantable timber can be prevented if the timber is utilized within from one to two years from the time that it was killed, depending on the species of wood and the locality—one year for pine (less in the Southern States) and two years for chestnut.

Forest tree nursery stock should be planted in ground that has been plowed deep late in the fall of the year in a region where injury by termites is common.

Marlatt [a] states regarding white-ant infestation in buildings that setting foundation beams or joists in concrete is only a partial protection, since in the settling of the house the concrete will crack and afford entrance to the insects. Some protection is afforded by removing decaying stumps or posts, etc., adjacent to buildings, by drenching infested timbers with kerosene, and by removing infested joists in cellars and drenching the ground where they were set with kerosene (or carbon bisulphid). Where the injury is confined to exposed woodwork in buildings, hydrocyanic-acid gas fumigation [b] is to be recommended, the infested beams and joists beneath being exposed, if possible, by opening up the floors.

Certain species of wood appear to be naturally highly resistant to termite attack. Species of wood that, so far as determined by test,[c] have been resistant to attack by our native termites are all tropical species and woods too expensive for ordinary use, including teak (*Tectonia grandis*) from Siam and Burma, greenheart (*Nectandra rodiæi*) [d] from South America and the West Indies, "peroba" (several species of *Aspidosperma*) from South America, and mahogany (*Swietenia mahoghani*) from tropical America. Hagen[e] states that, according to Kirby, "Indian oak" or teak (*Tectonia grandis*) and "ironwood" (*Sideroxylon*) of India are immune to attack by termites. This immunity (?) or relative resistance of ironwood is not due to hardness, since Asiatic termites attack the hardest wood, *Lignum-vitæ*, but to the presence in the wood of substances (as oils or alka-

[a] Op. cit.

[b] Howard, L. O., and Popenoe, C. H. Hydrocyanic-acid gas against household insects. U. S. Dept. Agr., Bur. Ent., Circ. 163, p. 8, November 29, 1912.

[c] Impregnation of wood to resist insect attack. Amer. Lumberman, no. 2009, p. 32, November 15, 1913.

[d] This wood has been superficially attacked by termites after 12 months' test; the wood was eaten to the depth of one-eighth inch.

[e] Hagen, H. A. Monographie der Termiten. Linnæa Entomologica, Bd. 10, p. 44–45, 1855.

loids) repellent or distasteful to termites.[a] The presence of tyloses or of gums may be factors in determining[b] the durability and resistance of hardwood species. Hagen further states that, while teak is not destroyed by termites, he believes that even teak will be attacked when it has become old or been long exposed to the air. Hagen states that it is useless to consider tannin as a preservative, since, according to Williamson, termites will destroy leather. Some species of woods native to the Philippine Islands are apparently immune to termite attack.

Capt. Ahern, Chief of the Philippine Forestry Bureau, quotes Foreman, p. 390, as stating[c] that the "anay," or native termite, "eats through most woods (there are some rare exceptions, such as 'molave,' 'ipil,' 'yacal,' etc.)." Capt. Ahern states that—

The following woods are not subject to attack by anay: "Dinglas" [*Eugenia bracteata* Roxb., var. *roxburghii* Duthie, family Myrtaceæ], "ipil" [*Afzelia bijuga* Gray, family Leguminosæ], "molave" [*Vitex littoralis* Dene, family Verbenaceæ], and "yacal" [*Hopea plagata* Vidal, family Dipterocarpeæ].

"Tindalo" [*Afzelia rhomboidea* Vid.] is attacked by "anay" when there is no other wood in the vicinity.

"Baticulin" [*Litsea obtusata* B. and H., F. Vill, fam. Laurineæ] is attacked by "anay," but is not damaged or destroyed, except such parts as are buried underground.

TEST WITH THE WHITE ANT.

Mr. D. N. McChesney, master mechanic at the depot quartermaster shops in Manila, found last February that his trunk (made of an American spruce) had been invaded by white ants and was almost entirely destroyed; the clothes contained in the trunk were also eaten. He placed the trunk on the ground and near it pieces of the following woods:

	Result of 30 days' contact with ants.
American woods:	
Oregon pine	Entered and eaten; a mere matter of time for complete destruction.
Bull pine	Eaten more readily than Oregon pine.
Spruce	Do.
Western hemlock	Not touched.
California redwood [*Sequoia sempervirens*].	Ants tried, but discontinued after a slight effort.
California white cedar	Do.
Native woods:	
Molave	Ate a little of it; deepest hole about one-fourth inch.
Narra [*Pterocarpus indicus* Wild., family Leguminosæ].	Ate a little of it; deepest hole about one-half inch.
Painted wood	Ants worked under paint and ate the wood readily.

[a] The quality of hardness in wood, while not rendering a species of wood immune to termite attack, is an important factor in determining the relative resistance of species of woods. Hardness is a factor in the grading of mahogany lumber.

[b] Gerry, M. "Tyloses: Their occurrence and practical significance in some American woods." Jour. Agric. Research, vol. 1, no. 6, p. 462–464, March 25, 1914.

[c] Ahern, G. P. Important Philippine woods. 112 pp., col. pls. Forestry Bur., Manila, P. I., January 2, 1901. See p. 91.

Hemlock and redwood[a] are badly honeycombed by our native species of termites on the Pacific coast, and California white cedar is honeycombed by the termites of the Pacific coast.

European cypress (*Cupressus sempervirens* Linn.) is reported[b] damaged by termites at Rochefort, France.

Cedrus deodar, from India, and *Cedrus atlantica*, of the mountains of northern Africa, are reported to be immune (?) to termite attack.

Red "deal" is less liable to attack than white "deal."[c]

The following three species of wood remained untouched by termites for three years in the District of Pretoria, Transvaal:[d] "Leadwood" (*Combretum prophyrolepsis*), "black ironwood" (*Olea laurifolia*), "vaalbosch" (*Brachylæna discolor*).

In case of certain species of pines, with an extremely resinous heartwood, as the "fatwood" of the longleaf pine (*Pinus palustris*) of the Southern States, while termites honeycomb the sapwood, the heartwood apparently is resistant. Odenbach states that turpentine is very repellent to termites in artificial nests. In southern Rhodesia[e] the wood of the "mopani" tree (*Copaifera mopani*) withstands termite attack for years, and is therefore very suitable for straining posts for fences, though unfortunately not a timber that can be cut and squared.

Tests of the relative resistance of various native and exotic woods have been begun, but as yet no definite conclusions can be drawn. The heartwood of the following native species of wood is relatively more resistant to attack by our native termites: Black locust; black walnut[f] (cases on record where heavy beams supporting flooring in a building in Baltimore, Md., were completely honeycombed); eastern white cedar (*Chamæcyparis thyoides*); eastern red cedar or juniper; bald cypress of the Southern States; western red cedar (*Thuja plicata*) of Washington, Oregon, and California; incense cedar (*Libocedrus decurrens*) of Oregon and California; and Monterey cypress (*Cupressus macrocarpa*) of California. All these species of woods, however, are attacked by termites.

---

[a] Parker, W. B. Loc. cit.

[b] Hagen, H. A. Monographie der Termiten. Linnaea Entomologica, Bd. 10, p. 1–144, 1855. See p. 133.

[c] French, C. Handbook of the destructive insects of Victoria, pt. 2, p. 141, Melbourne, 1893.

[d] Howard, C. W., and Thomsen, F. Notes on termites. Transvaal Agr. Jour., v. 6, No. 21, p. 85–93, illus., October, 1907; v. 7, No. 27, p. 512–520, April, 1909; v. 8, No. 29, p. 86–87, October, 1909.

[e] Jack, R. W. Termites or "white ants." Rhodesia Agr. Jour., v. 10, No. 3, p. 393–407, pl., February, 1913.

[f] Impregnation of wood to resist insect attack. Amer. Lumberman, No. 2009, p. 32, November 15, 1913.

Hagen [a] briefs the records of various travelers as to the immune (?) or termite-resistant wood species of the countries of the world. Froggatt [b] states that in Australia red pine is more resistant than clear pine; that "jarrah" is said to be resistant, though not immune; and that desert cypress when sawn up appears to be resistant, but in the form of logs is not immune. The Rev. Joseph Assmuth, S. J.,[c] of Bombay, India, states that "deal" and "pukka" teak are injured by termites; he gives photographs of the damaged specimens of wood. In answer to a letter of inquiry he states:

The "pukka" teak is what is called here in India "Burmese teak," *Tectonia grandis* L. "Pukka" means genuine; it is used here in opposition to the less reliable timber of "Malabar teak," though both come from the same species of wood. The difference of both lies, I am told, in the seasoning of the timber, or rather in the different mode of felling the trees. In Malabar they cut off a ring of bark from near the base of the tree, so that the tree dries up while standing still erect, and is then felled. This seems to cause a gradual withdrawal of the oils contained in the wood, which makes the wood more liable to the attack of white ants. In Burmah the tree is felled as it stands and allowed to dry up lying on the ground. Thus the peculiar oils remain in the wood and are preserved in it, and consequently this timber is less palatable to the white ants, and shunned by them until in course of time the oils evaporate also. Then the white ants go for it too. Such, at any rate, is my theory. I can't explain otherwise why the one sort is at once attached by white ants, whereas the other remains for a longer period, at least, immune. The case therefore is briefly this: Malabar teak (here also called "jungle teak") is attacked by the white ants from the beginning. Burmah or "pukka" teak remains safe for a certain period, sometimes longer, sometimes shorter, but it is not absolutely safe either.

"Dealwood" is the common European wood used for boxes and the like; it is usually timber of Abies, Picea, or Pinus. It is the wood most readily attacked by termites of different species.

Kanehira,[d] tabulates the results of experiments with a large number of species of woods as to their relative resistance to termite attack in Formosa, Japan. Reasons are advanced as to the probable causes which render the wood "termite proof" (?). The conclusions he draws can not be accepted without further details as to how the tests were conducted and after a longer period of experimentation. Certain of the woods he lists as "immune" are known to be attacked by termites.

METHODS OF OBTAINING PHOTOGRAPHS FOR THE ILLUSTRATIONS.

The photographs of the insects reproduced in this paper were made after a method devised by Mr. H. S. Barber, of the Bureau of Entomology. The specimens were placed either between horizontal

[a] Loc. cit.

[b] Froggatt, W. W. White ants. (Termitidæ.) Misc. Pub. 874, Dept. Agr. N. S. Wales, Sydney, 1905, p. 43–44.

[c] Assmuth, J. Wood-destroying white ants of the Bombay presidency. Jour. Bombay Nat. Hist. Soc., v. 22, no. 2, p. 372–384, 4 pls., September 30, 1913.

[d] Kanehira. On some timbers which resist the attack of termites. Indian Forester, v. 40, no. 1, p. 23–41, January, 1914.

glass slides submerged in alcohol or immersed in water in a chamber made by gluing glass slides to thin slips of rectangular cover glass with heated balsam. In this water-tight compartment the specimens can be placed in vertical or horizontal positions. Ether is used to clear out the cell, which is filled with boiled water, thus avoiding the formation of air bubbles. If the specimens are placed head downward, movements of the antennæ, due to vibration, can be avoided. Cells of various sizes are used, or one large cell can be utilized by placing thin slips of cover glass back of the specimens to hold them firmly in position. By clamping the cell to the lens holder of a dissecting microscope placed horizontally, focusing can be conveniently accomplished by adjustments of the screw.

The best results are obtained by etherizing recently killed specimens that have not been placed in alcohol. A 72 millimeter focal length lens brings out the characters to the best advantage, if the enlargement is 6 to 8 diameters.

Many of the photographs were taken by Mr. H. S. Barber and some by Mr. H. B. Kirk at the eastern field station. Most of them, however, were made by the photographic laboratory of the United States Department of Agriculture.

BIBLIOGRAPHY.[a]

This bibliography consists mainly of publications on our native termites or closely allied species; some little-known publications are included. Hagen, up to 1860, Froggatt, Holmgren, Escherich, and Feytaud give extensive bibliographies.

Andrews, E. A., and Middleton, A. R. Rhythmic activity in termite communities. Johns Hopkins Univ. Circ., n. s., 1911, no. 2 (whole no. 232), p. 26–34, illus., February, 1911.

Atkinson, G. F. Some Carolina insects. 1st Rpt. So. Car. Exp. Sta. for 1888, p. 19–56, 1889.

Banks, N. Two new termites. Ent. News, v. 17, no. 9, p. 336–337, illus., November, 1906. *Cryptotermes cavifrons*, from Florida, and *Termopsis laticeps*, from Arizona, described.

Bidie, G. White ants—termites eroding glass. Nature, v. 26, no. 675, p. 549, October 5, 1882.

Buckley, S. B. Description of two new species of termites from Texas. Proc. Ent. Soc. Phila., v. 1, p. 212–215, May, 1862 (1863). *Hamitermes* (*Termes*) *tubiformans*, from Texas, p. 212, and *Eutermes cinereus*, from Texas, described.

Casey, T. L. A new genus of termitophilous Staphylinidæ. Ann. N. Y. Acad. Sci., v. 4, p. 384–387, March, 1889.

Coryell, J. R. The termite pest of the old world. Sci. Amer., v. 59, no. 10, p. 151, September 8, 1888, illus.

Derry, D. E. Damage done to skulls and bones by termites. Nature, v. 86, no. 2164, p. 245–246, April 20, 1911.

Dixon, W. A. Protection from "white ants" and other pests. Nature, v. 85, no. 2148, p. 271, December 29, 1910.

[a] The references in the bibliography, as well as those in the footnotes, have been verified by the librarian of the Bureau of Entomology, Miss Mabel Colcord.

Fitch, A. Fourth Report on the Noxious and Other Insects of the State of New York, 1858, p. [8] or Trans. *Termes frontalis.* N. Y. State Agr. Soc., v. 17 (1857), p. 694, 1858.

Forbes, S. A. The white ant in Illinois. (*Termes flavipes* Kollar.) 19th Rpt. State Entomologist . . . of Illinois for 1893 and 1894, p. 190–204, 1895. Lists economic publications on termites.

Grant, R. D. [Ravages of *Termes flavipes*.] Trans. Acad. Sci. St. Louis, v. 3, Jour. of Proc., p. cclxix, November 19, 1877.

Hagen, H. A. Report on the Pseudo-Neuroptera and Neuroptera collected by Lieut. W. L. Carpenter in 1873 in Colorado. Ann. Rpt. U. S. Geol. Survey Ter. for 1873, by F. V. Hayden, p. 571–606, 1874.

White ants destroying living trees and changing foliage in Cambridge, Mass. Canad. Ent., v. 17, no. 7, p. 134–136, July, 1885.

The female of *Eutermes rippertii*. Psyche, v. 5, no. 157–159, May–July, 1889, p. 203–208.

Haviland, G. D. Observations on termites; with descriptions of new species. Jour. Linn. Soc. [London], Zool., v. 26, no. 169, p. 358–442, pls. 22–25, April 1, 1898.

Observations on termites or white ants. Ann. Rpt. Smithsn. Inst. for year ending June 30, 1901, p. 667–678, pl. I–IV, 1902.

Hubbard, H. G. Notes on the tree nests of termites in Jamaica. Proc. Boston Soc. Nat. Hist., v. 19, p. 267–274, December 26, 1877, printed March, 1878.

Insects affecting the orange, Washington, 1885. Chap. IX, p. 121–125, White ants or "wood-lice."

Kellogg, V. L. Are the Mallophaga degenerate psocids? Psyche, v. 9, no. 313, p. 339–343, May, 1902.

Knower, H. McE. The development of a termite—*Eutermes* (*Rippertii?*). A preliminary abstract. Johns Hopkins Univ. Circ., v. 15, no. 126, p. 86–87, June, 1896.

The embryology of a termite, *Eutermes* (*Rippertii?*). Jour. Morphol. [Boston], v. 16, no. 3, p. 505–568, pl. 29–32, August, 1900.

A comparative study of the development of the generative tract in termites. Johns Hopkins Hospital Bul., v. 12, no. 121–122–123, p. 135–136, 2 figs., Baltimore, April–May–June, 1901.

Lintner, J. A. Entomology. Proc. Albany Inst., v. 2, p. 48–50, 1878.

Osborn, H. On the occurrence of the white ant (*Termes flavipes*) in Iowa. Proc. Iowa Acad. Sci., v. 5, for 1897, p. 231, 1898.

Osten-Sacken, C. R. Extract from a letter by Baron R. Osten-Sacken, on the specimens of Termes found by him in California. Proc. Boston Soc. Nat. Hist., v. 19, p. 72–73, for January 3, 1877, June, 1877.

Packard, A. S. Third Report U. S. Entomological Commission, Washington, 1883, p. 326–329.

On the systematic position of the Mallophaga. Proc. Amer. Philos. Soc., v. 24, p. 264–272, 13 figs., September 2, 1887.

A Textbook of Entomology, New York, 1903.

Parker, W. B. California redwood attacked by *Termes lucifugus* Rossi. Jour. Econ. Ent., v. 4, no. 5, p. 422–423, October, 1911.

Riley, C. V., editor. Amer. Ent., v. 3 (n. s., v. 1), p. 15, January, 1880. Termitophilous insects collected by E. A. Schwarz recorded.

Riley, C. V., and Howard, L. O. Termites swarming in houses. U. S. Dept. Agr., Div. Ent., Insect Life, v. 6, no. 1, p. 35, November, 1893.

Scammell, E. H. White ants. Knowledge, n. s., v. 4, p. 10–12, January, 1907. Protection of wood by a newly devised process.

Schwarz, E. A. Staphylinidæ inquilinous in the galleries of *Termes flavipes*. Amer. Ent., v. 3 (n. s., v. 1), p. 15, January, 1880.

Termitophilous Coleoptera found in North America. Proc. Ent. Soc. Wash., v. 1, no. 3, p. 160–161, 1889.

SCUDDER, S. H. Remarks upon the American white ant. Proc. Boston Soc. Nat. Hist., v. 7, p. 287–288, 1860.

Further injury to living plants by white ants. Canad. Ent., v. 19, no. 11, p. 217–218, November, 1887.

More damage by white ants in New England. Psyche, v. 6, no. 177, p. 15–16, January, 1891.

The fossil white ants of Colorado. Proc. Amer. Acad. Arts and Sci., v. 19 (n. s., v. 11), p. 133–145, 1884.

SMITH, E. F. White ants as cultivators of fungi. Amer. Nat., v. 30, p. 319–321, April, 1896.

SNYDER, T. E. Record of the finding of a true queen of *Termes flavipes* Kol. Proc. Ent. Soc. Wash., v. 14, no. 2, p. 107–108, pl. 3, June 19, 1912.

Changes during quiescent stages in the metamorphosis of termites. Proc. Ent. Soc. Wash., v. 15, no. 4, p. 161–165, December, 1913.

STOKES, A. C. The sense-organs on the legs of our white ants. *Termes flavipes* Koll. Science, v. 22, no. 563, p. 273–276, November 17, 1893.

WARREN, E. Some statistical observations on termites, mainly based on the work of the late Mr. G. D. Haviland. Biometrika, v. 6, no. 4, p. 329–347, illus., March, 1909.

WHEELER, W. M. The embryology of *Blatta germanica* and *Doryphora decemlineata.* Jour. Morphol., Boston, v. 3, no. 2, p. 291–386, pl. 15–21, September, 1889.

The phylogeny of the termites. Biol. Bul., v. 8, no. 1, p. 29–37, December, 1904.

The fungus-growing ants of North America. Bul. Amer. Mus. Nat. Hist., v. 23, p. 669–807, pl. 49–53, September, 1907. Including Pt. IV, 1, The fungus-growing termites, p. 775–786.

RELATION OF TERMITES TO THE ORIGIN OF HOG-WALLOWS AND PRAIRIE MOUNDS.

BARNES, G. W. The hillocks or mound-formations of San Diego, California. Amer. Nat., v. 13, no. 9, p. 565–571, September, 1879.

BRANNER, J. C. Decomposition of rocks in Brazil—Burrowing animals—Ants. Bul. Geol. Soc. Amer., v. 7, p. 295–300, February 4, 1896.

Ants as geologic agents in the Tropics. Jour. Geol., v. 8, p. 151–153, February–March, 1900.

Natural mounds or hog-wallows. Science, n. s., v. 21, no. 535, p. 514–516, March 31, 1905.

Geologic work of ants in tropical America. Bul. Geol. Soc. Amer., v. 21, p. 449–496, fig. 11, pl. 35, August 20, 1910.

FORSHEY and COPES. Mounds. Proc. New Orleans Acad. Sci., v. 1, no. 1, p. 18–20, March 1, 1854.

HILGARD, E. W. Physico-geographical and agricultural features of the State of California. U. S. Dept. Int., Census Off. 10th Census U. S., v. 6. Report on cotton production in the United States, Part II, p. 663–741. Hog-wallows, p. 676–677, 693.

LE CONTE, J. Prairie mounds. Proc. Cal. Acad. Sci., v. 5, p. 219–220, January, 1874.

Hog-wallows or prairie mounds. Nature, v. 15, p. 530–531, April 19, 1877.

McCOOK, H. C. Note on mound-making ants. Proc. Acad. Nat. Sci. Phila., 1879, p. 154–156, 1880.

TURNER, H. W. Hog-wallow mounds. U. S. Geol. Survey, Ann. Rept. 17, 1895–96, Pt. I, p. 681–683, pl. 33, 1896.

VEATCH, A. C. Formation of natural mounds—Ant-hill theory. U. S. Geol. Survey, Prof. Paper no. 46, p. 55–56 and 58–59, 1906.

WALLACE, A. R. Glacial drift in California. Nature, v. 15, p. 274–275, January 25, 1877.

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
20 CENTS PER COPY

INDEX.

55514—16——2